

National Aeronautics and Space Administration



Independent Verification and Validation

NASA IV&V 2004

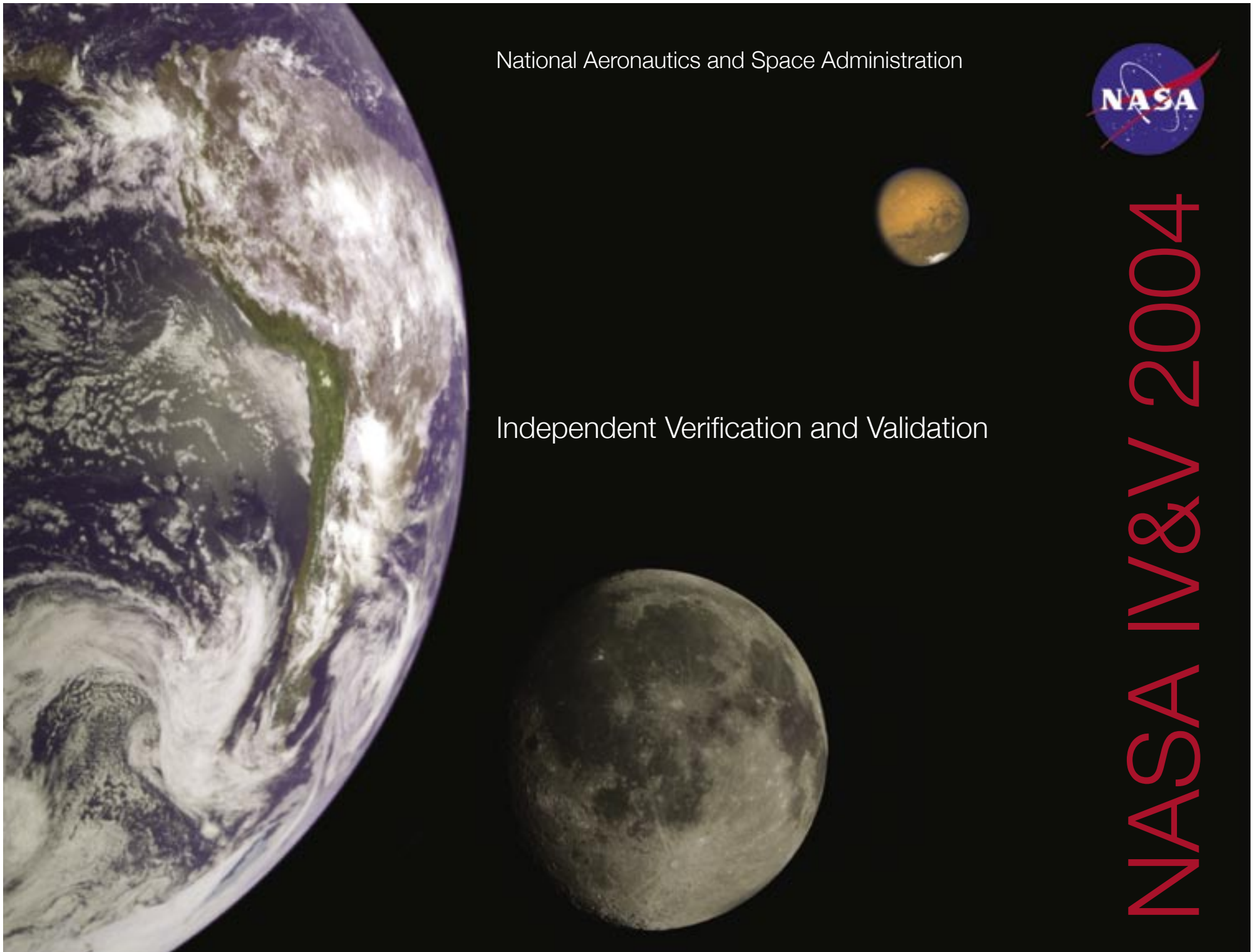


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FROM THE FORMER NASA ADMINISTRATOR

“Ten years ago, we established the Fairmont IV&V Facility to bring focused assurance to NASA’s flight software efforts - over this decade, the utility of the operation is evident every day. While the complexity of software and avionics have increased dramatically since the inception of the IV&V Facility, we continue to fly successful missions with robust software. As we renew our commitment to safety and mission success, we continue to see the value and importance of IV&V. I congratulate the Fairmont team for their fine work and continued commitment to NASA’s missions.”

Sean O’Keefe



NASA IV&V FACILITY'S VISION

Be acknowledged as the preeminent organization applying and improving independent verification and validation for software and systems.

NASA IV&V FACILITY'S MISSION

NASA IV&V provides assurance for our customers' safety and mission critical software in the areas of safety, reliability and availability; performs leading-edge research that improves IV&V and software assurance methods, practices, and tools; participates in the vitality of the community, as well as engages the public in the experience and benefits of exploration and discovery.

LETTER FROM THE DIRECTOR

We look back on the year 2004 as one of meaningful celebration and impressive achievement. The work of IV&V and its highly skilled cadre of project managers, researchers, engineers and partner contractors increased the effective application of software independent verification and validation across NASA. The dedicated members of our Outreach team worked with educators and community members to inform and motivate hundreds of West Virginia citizens and students from elementary schools to universities. The entire staff participated in a vigorous process of management systems review, innovation and implementation, reflecting our commitment to One NASA initiatives.

We value the support of our colleagues throughout NASA, our partners in the discipline of IV&V, and the community in which we live and work that allows us to participate fully in NASA's mission:

To understand and protect our home planet

through our work with such projects as AURA, GOES-N, NPP, SDO, THEMIS, AIM, SSP and ISS, and our SARP and Facility Research Initiatives.

To explore the universe and search for new life

through our work with such projects as MRO, MESSENGER, SWIFT, CREAM, KEPLER, DAWN, SSP, ISS and the James Webb Telescope, and our SARP and Facility Research Initiatives.

To inspire the next generation of explorers

through our Community and Student Outreach, the Educator Resource Center, and the Co-op, Intern, and Apprentice Programs.

...as only NASA can.

In 2004, NASA IV&V was honored with awards that publicly acknowledged our efforts to rise to the challenges of our mission. As you read about those awards, I ask you to join me in honoring the commitment to excellence displayed by our NASA IV&V family every day without public notice, but with profound effect.

I hope you will find much to interest and inspire you in this document. I encourage you to seek further information by visiting the web sites noted in each section. As we look back on a decade of excellence and innovation and forward to a limitless future, I welcome your comments on our work and our vision.

Sincerely,



Nelson "Ned" Keeler
Director

On May 28, we celebrated the Tenth Anniversary of our Facility. Dedicated in 1994, NASA IV&V has experienced the fast-growing and far-reaching impact of its mission to:

Pillar I

Ensure our customers' mission and safety critical software meets all requirements for safety, reliability and availability;

Pillar II

Perform leading-edge research that improves IV&V and software assurance methods, practices and tools;

Pillar III

Participate in the vitality of the community, as well as engage the public in the experience and benefits of exploration and discovery.

A DECADE OF EXCELLENCE AND INNOVATION

The year 2004 marked a milestone established by both time and commitment. The Tenth Year Anniversary of our Facility, dedicated on June 1, 1994 as the flagship of West Virginia's I-79 Technology Park, was celebrated on May 28, 2004. Ten years ago the NASA IV&V Facility was built through a grant from NASA to West Virginia University (WVU) and continues to be operated and maintained for NASA's use under a contract with the WVU Research Corporation.

The day's events included a showcase of exhibits by NASA IV&V, West Virginia University, Facility contractors, affiliates and partners. The ceremony included welcoming remarks from the NASA IV&V Facility Director Ned Keeler and keynote addresses by Bryan O'Connor, NASA's Chief Safety and Mission Assurance Officer, and Congressman Alan B. Mollohan. In addition, Congressman Mollohan read a letter from Senator Robert C. Byrd congratulating the IV&V Facility on its tenth anniversary. A luncheon concluded the day's celebration with remarks from Dr. John Weete, Vice President for Research and Economic Development at West Virginia University.

Throughout 2004, as we planned our celebration, we also reviewed a decade of commitment to our mission, adherence to our values, and the ongoing work of reaching our goals. As we assessed the work of the past, we continued the good work begun in 1994, and thoughtfully deliberated on our future in a stringent review of our Facility's Implementation Plan. A ten-year period of such impressive growth demanded that we dedicate ourselves to further define and strengthen the three pillars that represent our mission: IV&V Services, Research and Outreach. At the same time, we focused on the foundation on which those pillars stand, the management systems—financial, human, information, technological—and the physical management of the Facility itself.



Nelson "Ned" Keeler became the IV&V Facility Director in June 2001. Since then he has had the pleasure of supporting an increase in the IV&V Facility's services, research, and outreach accomplishments. He began his career in the Coast Guard where he earned his aviator wings and an international reputation for research and development. After retiring from the Coast Guard, he joined NASA's Space Station Freedom program. He then tried his hand at private industry but his heart brought him back to NASA. Ned takes great pride in the energized IV&V Facility's efforts to become a more effective and efficient organization.



Bryan O'Connor and Congressman Alan B. Mollohan speak at the Tenth Year Anniversary ceremony.

Over the past ten years, we have dedicated ourselves to bringing life to our vision to **“Be acknowledged as the preeminent organization applying and improving independent verification and validation for software and systems.”**

The annual review of our Implementation Plan renews our commitment to our stated goals; those we have reached, and those we continue to strive towards. That commitment manifested itself during this past year through a variety of successful activities such as:

- The transition of funding IV&V Services from individual project budgets to NASA corporate G&A was completed in 2004, fundamentally changing the process by which IV&V projects are established and supported. The establishment of a partnership with the NASA Engineering & Safety Center (NESC) and becoming part of the Safety & Mission Assurance (SMA) Readiness Review process significantly strengthened the Facility's role throughout NASA.
- Program standardization enhanced the Facility's quality management system, and the 2004 ISO recertification was completed, demonstrating the commitment to quality standards across the entire organization.
- The Facility was the prime sponsor of the Office of Safety and Mission Assurance (OSMA) Software Assurance Symposium (SAS), which presents the results of NASA's OSMA sponsored research initiatives. The 2004 SAS Symposium exhibited expertise in IV&V and related research and effectively stimulated interest in IV&V and advanced its principles and practices by bringing together the best and brightest on the topic.

THOM COCHRAN, MISSISSIPPI
ARLEN SPECTER, PENNSYLVANIA
PETER V. DOMENICI, NEW MEXICO
CHRISTOPHER S. BOND, MISSOURI
MITCH MCCONNELL, KENTUCKY
CONRAD BURNS, MONTANA
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HARRY REID, NEVADA
HERB KOHL, WISCONSIN
PATTY MURRAY, WASHINGTON
BYRON L. DORGAN, NORTH DAKOTA
DANIE FERSTEN, CALIFORNIA
RICHARD J. DURBIN, ILLINOIS
TIM JOHNSON, SOUTH DAKOTA
MARY L. LANDRIEU, LOUISIANA

JAMES W. MORHARD, STAFF DIRECTOR
TERRENCE E. SALVAIN, MAJORITY STAFF DIRECTOR

United States Senate
COMMITTEE ON APPROPRIATIONS
WASHINGTON, DC 20510-6025
www.senate.gov/appropriations

May 28, 2004

Employees and Friends of the NASA
Independent Verification and Validation Center
Fairmont, West Virginia

Dear Friends:

Please accept my sincerest congratulations as the NASA Independent Verification and Validation (IV&V) Center celebrates its tenth anniversary today. The IV&V Center holds a special place in my heart as it was one of the first of many federal high technology entities that I have been able to bring to the state, believing that West Virginia should and could play a role in national technology programs.

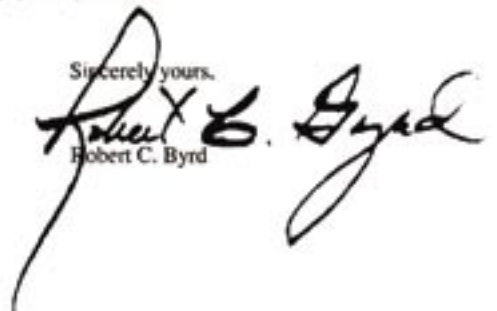
With NASA's increasing reliance on software and the need for the software to perform as intended to achieve mission success, the IV&V Center has already firmly established itself as a crucial risk-management and cost-savings mechanism throughout the NASA complex. The IV&V Center team should be rightfully proud of the contributions it is making toward a wide range of NASA missions, including, most recently, the "Spirit" and "Opportunity" rovers that landed on Mars earlier this year. I hope you will accept my personal appreciation for your commitment and hard work in ensuring that NASA missions go as planned and that potential problems are found at a very early stage. As I have said many times, you do not have to leave the hills of West Virginia to reach the stars. I added \$10 million to a federal appropriations bill to support the construction of the IV&V Center, and I am proud that this investment has yielded a decade of significant national achievement.

The IV&V Center has also well exceeded my prediction that it would be a catalyst for economic activity in this region. When we dedicated the center a decade ago, forty-four employees started up its operation and the facility stood virtually alone in what is now known as the I-79 Technology Park. Today, due primarily to our own economic development dynamo, better known as Congressman Mollohan, the I-79 Technology Park, which has been expanded from 120 acres to over 500 acres, is also the home of the Alan B. Mollohan Innovation Center, the Lockheed Martin-Fairmont State Training Center, and the National White Collar Crime Center. Together, with the IV&V Center, the I-79 Technology Park now supports over 800 employees. I understand that with the completion of the Institute of Software Research, as well as several other major building and infrastructure construction projects, West Virginia High Technology Consortium officials anticipate that employee levels will continue to climb over the next ten years.

In closing, I thank you for the opportunity to send my best wishes to you today, and, most certainly, for the opportunity over the years to help the IV&V Center achieve a level of excellence that is seconds to none. I hope that you will keep up the good work and enjoy today's event.

With warm wishes, I am

Sincerely yours,


Robert C. Byrd

RCB:tsb

- The increased number and variety of projects and initiatives of the Facility resulted in a 14% increase in civil servants employed, and West Virginia University and several other academic institutions partnered with IV&V to conduct important and exciting research.
- Renovations took place in 2004 to accommodate the lease of space to the National Oceanic and Atmospheric Administration (NOAA) for one of its super computers, providing significant offset to NASA Operations and Management costs.
- A host of successful Outreach activities took place in 2004. The annual “Day in the Park” brought 850 seventh graders from throughout West Virginia to the Facility for the most successful event to date. Further honoring our commitment to “inspiring the next generation” and in response to greater demands on IV&V’s Educator Resource Center, the new Student Outreach Program was established in April 2004 and had an immediate and far-reaching impact on the community.

We begin this document with a description of the work of our Facility to further the reader’s understanding of our mission.

The work conducted in 2004, represented by the pillars of IV&V Services, Research and Outreach, will be detailed in dedicated sections of this document. We conclude by reviewing the building blocks of our foundation—the management of NASA’s IV&V Facility—and with our vision for the future.

Our ten-year milestone afforded us the opportunity to acknowledge in public and private forums that we are proud of our place in our community; proud of the exacting work done on behalf of NASA’s human and robotic missions by our project managers and engineers; and proud of the leading-edge research being done in

collaboration with academics and contractors alike to strengthen IV&V’s impact. As you read this document, we hope that you will be convinced, as we are, of the insightfulness of Senator Byrd’s vision,

“You do not have to leave the hills of West Virginia to reach the stars.”

—Senator Robert C. Byrd



The pillars of our mission are IV&V Services, Research and Outreach. The IV&V Services pillar encompasses all aspects of our fundamental responsibility—the delivery of the highest quality state-of-the-art independent verification and validation services to our customers. The Research pillar represents the myriad research efforts undertaken to improve and advance software assurance methods, practices and tools. The Outreach pillar stands as a solid commitment to effectively engage the public in the experience and benefit of exploration and discovery, and to participate in the vitality of the communities we serve in a number of proactive activities, from education to community development.

The ultimate success of the three pillars rests upon the ability to effectively and efficiently carry out our mission every day. Thus, the diagram shows an underlying foundation of administration, operations, and maintenance through facility management, management systems, and a well-administrated organization.

OUR PEOPLE

The work performed by the IV&V Facility staff supports the software assurance program throughout NASA. Our work is aimed at betterment of all NASA safety and mission critical software efforts, ranging from the human-rated space flight and robotic science missions to the NASA Integrated Financial Management Program.

During 2004, the Facility added six civil servants (a total of 43, representing a 14% growth) to its ranks. From administrative support to additional project managers, the Facility has been successful in recruiting talented individuals from West Virginia and throughout the nation to join the NASA family.

The NASA IV&V staff also works closely with contractors who have significant domain knowledge and experience. During 2004, the IV&V Facility involved 178 contractor employees who skillfully provided services across a variety of projects. Approximately 105 Full Time Equivalent (FTE) contractors were engaged on-site supporting IV&V initiatives, and 73 FTE contractors resided off-site with our customers. In addition, 38 researchers worked with us on initiatives to improve software assurance in NASA.

OUR PARTNERS

Throughout the past ten years, the IV&V Facility has developed an expansive array of collaborations and partnerships. In 2004, IV&V successfully joined efforts with businesses and institutions from across the State and the nation to further NASA's mission. The IV&V Facility also collaborates with many NASA offices and programs in an effort to strengthen the "One NASA" initiative. Many of these affiliations are software-related and assist in the enhancement of software assurance and software engineering to advance state-of-the-art tools, techniques, and methodologies.

In addition to efforts focusing on direct IV&V project work, there were a number of research efforts underway in 2004. The Facility continued to expand its presence, especially in practical and applied initiatives in collaboration with researchers from West Virginia University and other academic institutions around the country.



The map above shows where NASA IV&V Services were being provided in 2004.

OUR WORK

Software Independent Verification & Validation (IV&V) is a systems-engineering process employing rigorous methodologies for evaluating the correctness and quality of the software products throughout the development life cycle. Software IV&V is adapted and tailored to the characteristics of the project.

Independent (We are ensuring objective analysis.)

- Technical: IV&V prioritizes its own efforts
- Managerial: Independent reporting route to NASA Headquarters
- Financial: Budget is allocated by NASA to the IV&V Facility such that IV&V effectiveness is not compromised

Verification (Are we building the product right?)

- The process of determining whether or not the products of a given phase of the software development life cycle fulfill the requirements established during the previous phase.
- The process of determining if the product is internally complete, consistent and correct, and if it will support the next phase of development.

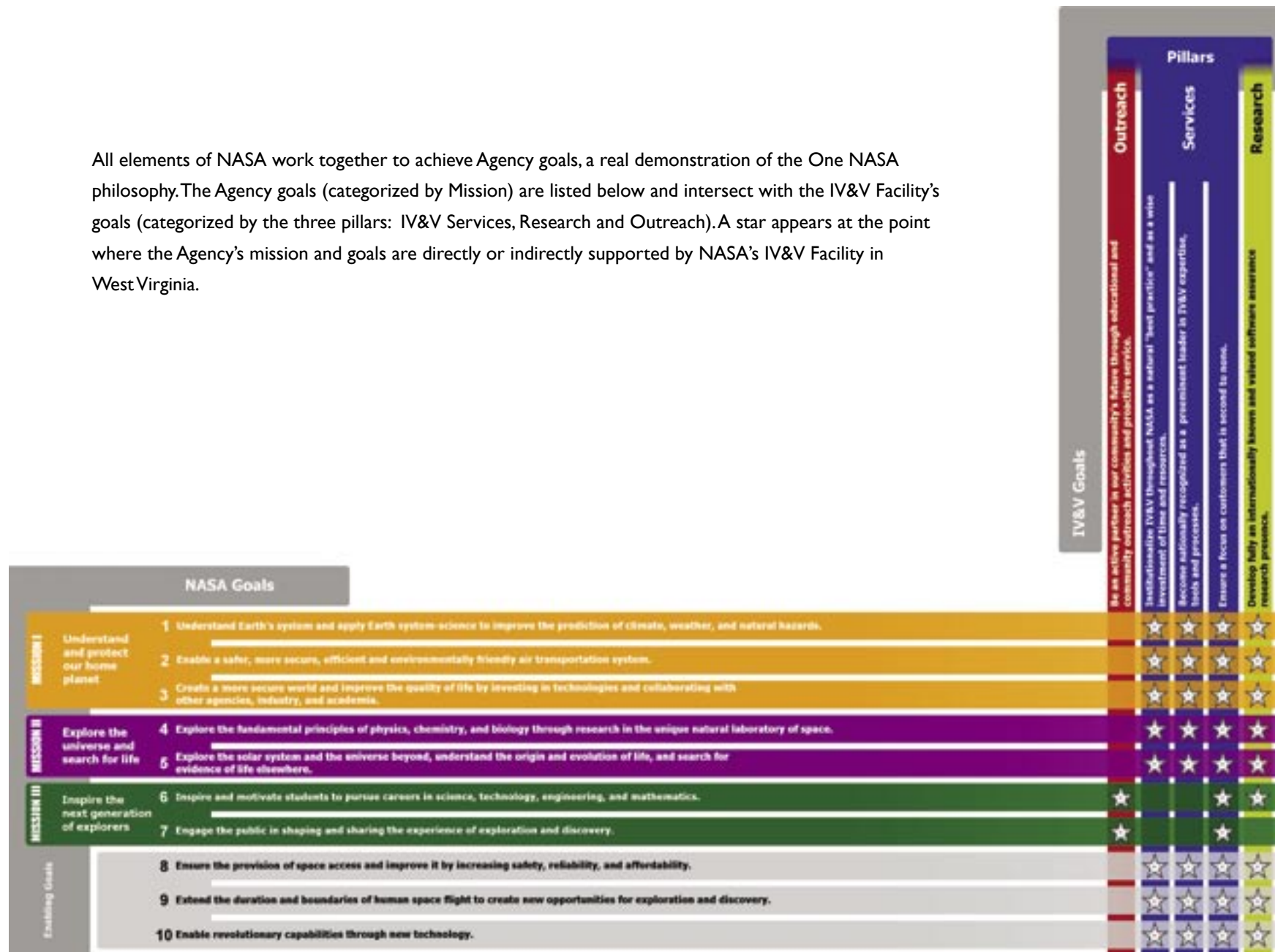
Validation (Are we building the right product?)

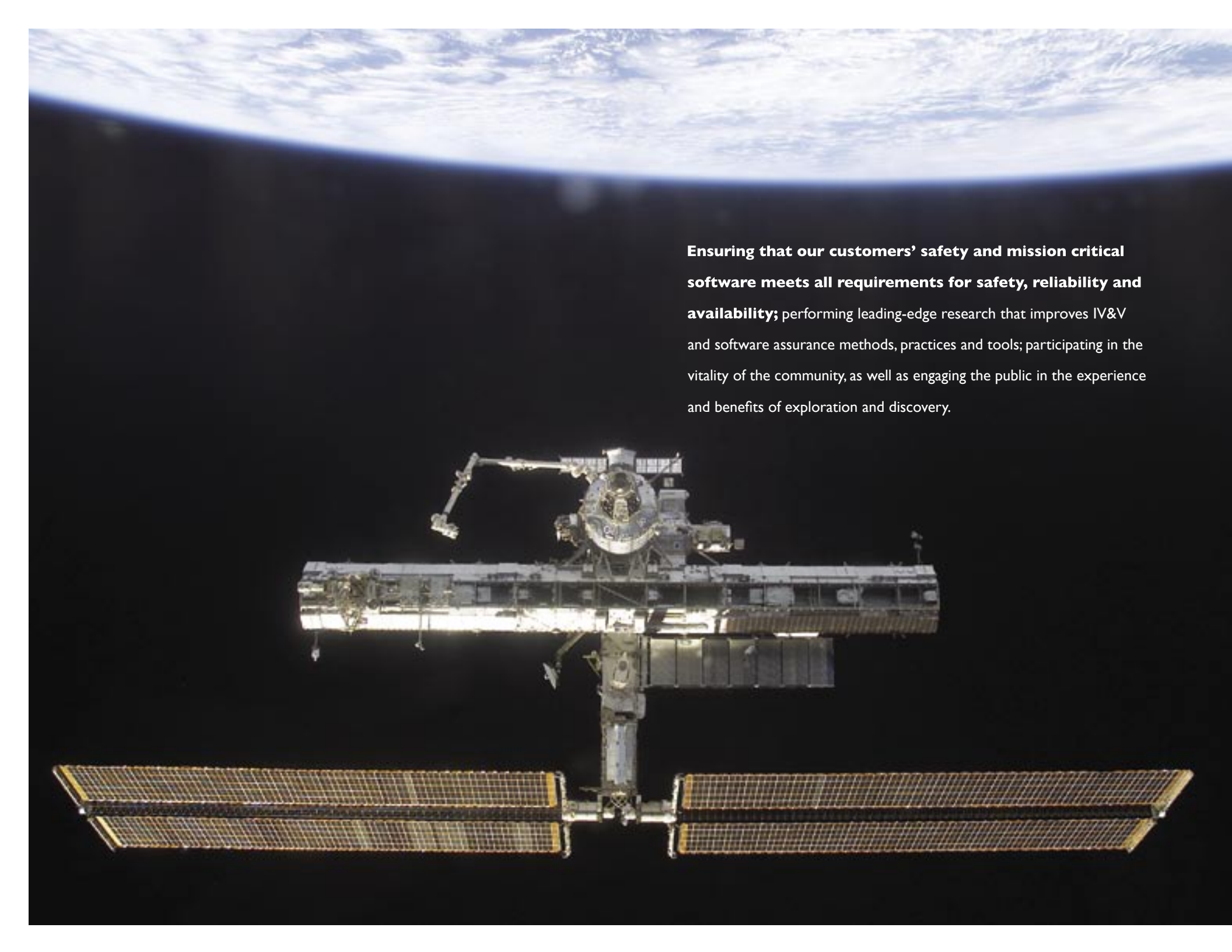
- The process of evaluating software throughout its development process to ensure compliance with software requirements. This process ensures
 - Expected behavior when subjected to anticipated events
 - No unexpected behavior when subjected to unanticipated events
 - System performs to the customer's expectations under all operational conditions

A series of steps is performed to establish IV&V involvement on a project. The Office of Safety and Mission Assurance at NASA Headquarters provides a prioritized list of software projects across the Agency slated to receive IV&V each fiscal year. In order to support budget formulation, the IV&V Facility estimates the cost for that portfolio of projects. IV&V then initiates a planning and scoping effort for new missions (those not continuing from the previous year). The planning and scoping effort includes developing an analysis of the criticality and risk of the project's software systems and components. This allows IV&V to develop a life cycle IV&V approach. IV&V creates a start-up assessment report, which includes this criticality and risk information, a list of appropriate IV&V tasks, and a refined estimate of the IV&V cost for the planned work. Finally, IV&V develops a detailed IV&V Plan in accordance with the IV&V Work Breakdown Structure (WBS) and IV&V activities begin.

Software IV&V has been demonstrated to be an effective technique on large, complex software systems to increase the probability that the software being delivered meets requirements and is safe, within cost, and within schedule. When performed in parallel with the development life cycle, software IV&V provides for the early detection and identification of risk elements. The project is then able to take action to mitigate these risks early in the life cycle, often reducing cost, schedule impact, and the need for rework, while increasing the system's safety.

All elements of NASA work together to achieve Agency goals, a real demonstration of the One NASA philosophy. The Agency goals (categorized by Mission) are listed below and intersect with the IV&V Facility's goals (categorized by the three pillars: IV&V Services, Research and Outreach). A star appears at the point where the Agency's mission and goals are directly or indirectly supported by NASA's IV&V Facility in West Virginia.



A photograph of the International Space Station (ISS) in orbit above Earth. The station's complex structure, including the central truss, multiple modules, and large solar panel arrays, is clearly visible against the black background of space. The Earth's curved horizon and white cloud cover are seen in the upper portion of the image.

Ensuring that our customers' safety and mission critical software meets all requirements for safety, reliability and availability; performing leading-edge research that improves IV&V and software assurance methods, practices and tools; participating in the vitality of the community, as well as engaging the public in the experience and benefits of exploration and discovery.



PILLAR I: IV&V SERVICES

Goal: Deliver and institutionalize high quality IV&V services throughout NASA.

Goal: Be acknowledged as the preeminent leader in IV&V expertise, tools and processes.

Goal: Ensure a continual focus on external and internal customer service that is second to none.

OVERVIEW

The NASA IV&V Facility plays a vital role across the entire spectrum of NASA's mission. In 1994, the Facility proudly took on its first project—the International Space Station. Over the last ten years, IV&V has increased its IV&V Services staff to adjust to a fast-expanding portfolio of projects. When the Facility was dedicated, there were a handful of civil servants to perform all the tasks required to support its work, from project management to handling daily operations at the Facility. In 2004, 22 civil servants brought their impressive talents to the IV&V Services group alone. The Services Project Managers and Senior Leads managed IV&V efforts on 34 projects in the last year. Services and projects range in size and scope from the continuing support of the International Space Station to analysis of Digital Control Interface Unit (DCIU) flight software components on the Dawn mission. In addition to managing IV&V work, many of the Project Managers act as points of contact for research initiatives, helping to ensure that active IV&V Services work benefits from research, as well as providing real-life IV&V experience to the research initiatives.

IV&V's work on a given software development project is determined by the results of the Criticality Analysis performed by IV&V. The Criticality Analysis process assesses each software component against a set of criteria to determine its relative importance. The criteria include the size of the development effort, its complexity, the risk involved, and the consequences if the software component were to fail. The result of this process is a Critical Functions List (CFL) which documents the software integrity level of each software component. Based on the Critical Functions List, IV&V creates a plan detailing what tasks will be performed on each component—more critical functions demands more extensive analysis.



Marcus S. Fisher, a West Virginia native and graduate of WVU, began his civil service career at NASA IV&V in 2001. He now manages the largest IV&V project at the Facility, providing IV&V services for the International Space Station. NASA awarded Mr. Fisher the prestigious Space Flight Awareness Award in 2004. The award was given in recognition of his leadership, effort, dedication and attention to detail on the Software Independent Assessment for the Space Shuttle Extravehicular Mobility Unit (EMU) Enhanced Caution and Warning System (eCWS). NASA's Office of Space Flight sponsors the Space Flight Awareness (SFA) Employee Motivation and Recognition Program, which focuses on excellence in quality and safety for the lives of the astronauts, for mission success, and for the success of America's space program. The "SFA Honoree Award" event was held at the Disney World Coronado Springs Resort, Lake Buena Vista, Florida, August 23-27. The event included a dinner held in honor of the recipients, and a VIP tour of the Kennedy Space Center. Astronaut Pamela Melroy presented the award to Mr. Fisher at the SFA awards ceremony.

The software/system development life cycle (SDLC) has phases which produce specific products. IV&V tailors its analysis based on the phase/product. Staying in step with the development life cycle provides for earlier recognition and resolution of issues, thus reducing the cost of rework and maximizing the benefits of IV&V to the project.

- *Concept Phase:* Verify candidate reuse software will satisfy the domain of the new system; assess the proposed architectural schema for feasibility; analyze the system requirements.
- *Requirements Phase:* Verify that system and software requirements are correct, complete, traceable and testable; verify that test plans and acceptance criteria are sufficient to validate system requirements and operational needs; ensure that testing methods are sufficient to verify and validate software requirements; verify that the correct software development, management, and support processes are in place.
- *Design Phase:* Verify the design will satisfy the requirements levied against it; ensure test plans and test environments are sufficient to verify and validate software and operational requirements; verify that the design does not have any characteristics that will cause it to fail under operational scenarios.
- *Coding Phase:* Verify the code reflects the design; verify the code is correct; verify that test cases trace to and cover software requirements and operational needs; verify that software test cases, expected results, and evaluation criteria fully meet testing objectives; analyze selected code unit test plans and results to verify full coverage of logic paths, range of input conditions, error handling, etc.

- *Test Phase:* Verify correct disposition of software test anomalies; validate software test results versus acceptance criteria; verify tracing and successful completion of all software test objectives; in some cases, IV&V may independently test highly critical software.
- *Operational Phase:* Verify that regression tests are sufficient to identify adverse impacts of changes.

Software IV&V is a value-added and necessary approach to ensuring that software is fit for operations and meets its requirements for safety, availability and functionality with the shared goal of mission success with the project.

In 2004, NASA launched or prepared to launch six science missions and delivered one air traffic control enhancement system. The IV&V Facility provided significant independent verification and validation services for these missions:

- 1) The Aura spacecraft, launched in July, is a mission that is investigating the dynamics of Earth's atmosphere.
- 2) MESSENGER (short for MErcury Surface, Space ENvironment, GEOchemistry, and Ranging) spacecraft, launched in August, is on a mission to map the surface of Mercury.
- 3) The Swift Gamma-Ray Burst Mission, launched in November, is on its way to pinpoint the location of distant yet fleeting explosions that appear to signal the births of black holes.
- 4) The Cosmic Ray Energetics And Mass Balloon Experiment (CREAM) instrument software is preparing to observe cosmic ray spectral features and changes that might be related to features of supernovas.

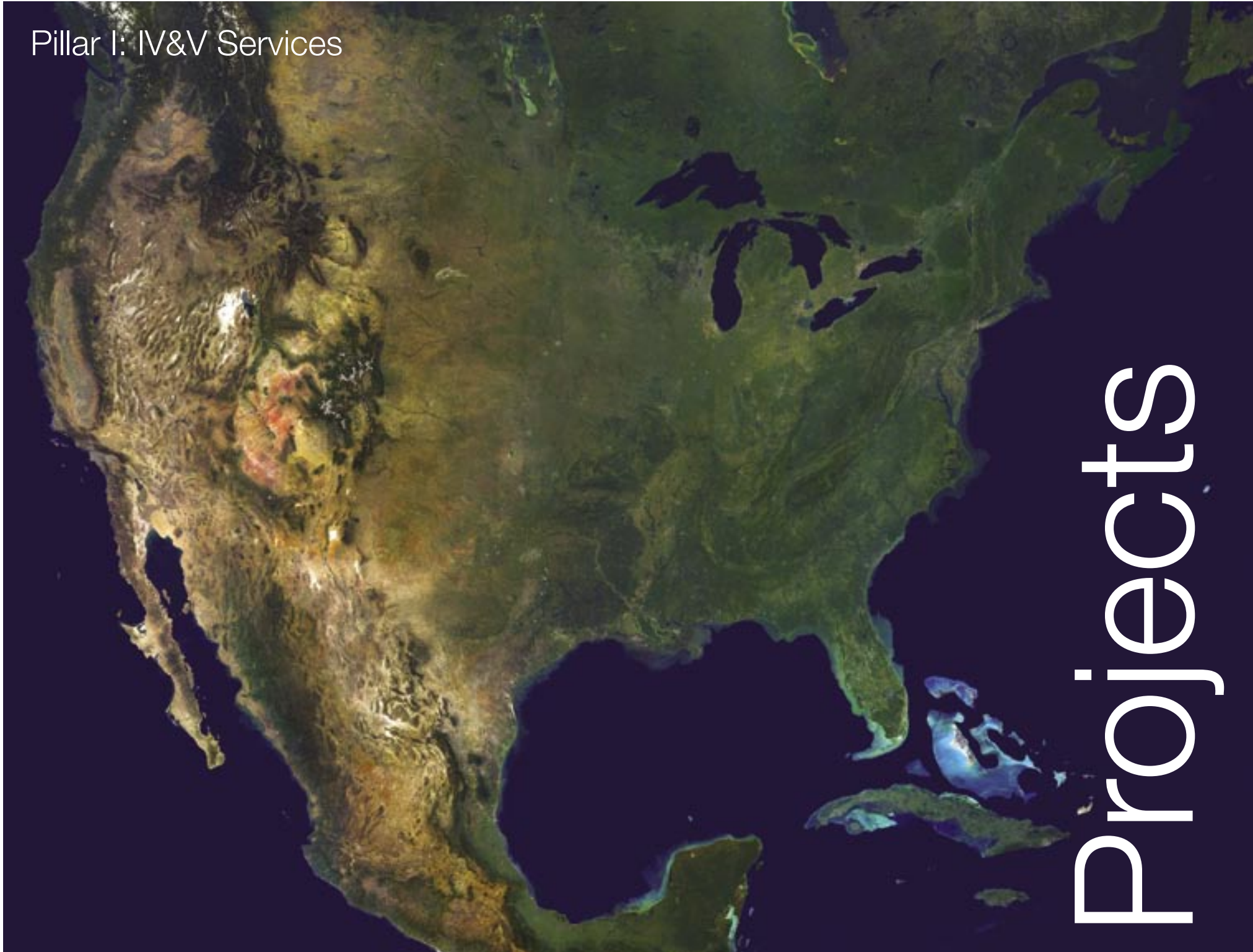


Shown above is the Space Shuttle Extravehicular Mobility Unit (EMU).

- 5) The Demonstration for Autonomous Rendezvous Technology (DART) project is ready to launch. A flight demonstrator vehicle designed to test technologies required to locate and rendezvous with other spacecraft, DART is unique in that all of the operations will be autonomous and controlled by computers.
- 6) The Space Shuttle Extravehicular Mobility Unit (EMU) enhanced caution and warning system (ECWS) monitors the primary spacesuit life support subsystem.
- 7) The Advanced Air Transportation Technologies (AATT) project was completed in September 2004. The major focus of the AATT project was to improve the capacity of transport aircraft operations at and between major airports in the National Airspace System (NAS) by developing tools and concepts to help improve the air traffic management and control process from gate-to-gate.

Pillar I: IV&V Services

Projects



ACTIVE AEROELASTIC WING (AAW)

IV&V Project Manager: Markland Benson

IV&V Contractor: Titan

NASA's Dryden Flight Research Center, Edwards, Calif., in cooperation with the U.S. Air Force Research Laboratory (AFRL) and Boeing Phantom Works, is researching a high-tech adaptation of the Wright Brothers rudimentary "wing-warping" approach to aircraft flight control in the Active Aeroelastic Wing (AAW) flight research program. The focus of AAW research is on developing and validating the concept of aircraft roll control by twisting a flexible wing on a full-size aircraft. The aerodynamic forces acting on the traditional aircraft control surfaces, such as ailerons and leading-edge flaps, will be used to twist a flexible wing to provide aircraft roll maneuvering control. The test aircraft chosen for the AAW research is a modified F/A-18A obtained from the U.S. Navy in 1999.

On AAW, the stiff wing skin panels of the F/A-18A have been replaced by more flexible panels. Additional actuators have been installed to allow independent control of the inboard and outboard flaps. New control software has been incorporated to take advantage of the wing modifications. Together, these modifications should allow the AAW aircraft to take advantage of aerodynamic forces by twisting the wings in flight to provide better roll control than on the baseline F/A-18A.

IV&V Facility analysts reviewed AAW planning documents and preliminary requirements and design documents to assess the degree to which these documents were complete, consistent, and would provide for a successful software development effort.

IV&V recommended enhancements to the Software Development Assurance Plan to improve its descriptions of assurance activities and use of terminology. IV&V pointed out discrepancies between copies of process documentation accessible on Dryden Flight Research Center's (DFRC) intranet and extranet. Based on IV&V's recommendation, DFRC took action to ensure that off-site project representatives would be able to access the same up-to-date process documentation as those residing on-site. The DFRC Safety and Mission Assurance organization added tasks to their planned work based on IV&V's assessment of AAW, which helped improve confidence in the software.

For further information about AAW, visit <http://www.nasa.gov/centers/dryden/research/AAW/index.html>.



The upper wing surfaces of the Active Aeroelastic Wing F/A-18 test aircraft are covered with accelerometers and other sensors during ground vibration tests at the NASA Dryden Flight Research Center.

ADVANCED AIR TRANSPORTATION TECHNOLOGY (AATT)

IV&V Project Manager: Peter Medley

IV&V Contractor: Titan

AATT stemmed from a research project undertaken by Ames Research Center to update and improve the tools used by air traffic control operators. The primary tools that were developed were Multi-Center Traffic Management Advisor (McTMA), Direct-To (D2) and Surface Management System (SMS). The final phase of the project was to transition the tools to the Federal Aviation Agency (FAA) for test and development.

The IV&V Facility provided a systems engineering support role for AATT, which included defect analysis of existing and newly generated software as well as documentation support for those artifacts that were transitioned to the FAA. In support of AATT, IV&V analysts provided reverse engineering of existing code so as to provide the necessary documentation to ensure the quality and testability of the generated tools.

IV&V provided detailed post analysis technical reports to the project. The technical reports provided the project with a sound foundation of traceability as well as a high confidence level in the quality of the project as it was transferred to the FAA. The analyst on-site at the Ames Research Center was commended by the AATT Project Office for his dedicated and tireless efforts over a 7-year period. IV&V's participation in the AATT project ended in October of 2004 with the successful transition of all documents to the FAA.

For further information about AATT, visit <http://www.asc.nasa.gov/aatt/>.

AERONOMY OF ICE IN THE MESOSPHERE (AIM)

IV&V Project Manager: Ken Vorndran

IV&V Contractor: SAIC

The AIM mission is part of NASA's Small Explorers (SMEX) program and is currently slated for launch in Fall 2006. The AIM mission will provide unprecedented advances in the understanding of noctilucent or "night shining clouds." The overall goal of the AIM mission is to study why noctilucent clouds form and why they vary.¹

By measuring noctilucent clouds and the environment in which they form, we will learn more about the connection between these clouds and the meteorology of the mesosphere. In the end, this will provide the basis for study of long-term variability in the mesospheric climate and its relationship to global climate changes.¹

The results of the AIM mission will be a rigorous validation of predictive models that can reliably use past changes and present trends of noctilucent clouds as indicators of global change. This goal can only be achieved by a complement of instruments on-board the AIM



Noctilucent clouds can be seen by sky watchers on Earth glowing in the night sky after sunset.

satellite which will be orbiting Earth at an altitude of 550 km. These instruments will take wide angle photos of noctilucent clouds, measure their temperatures and chemical abundances, monitor dusty aerosols, and count meteoroids raining down on Earth, all of which are critical factors associated with the formation of noctilucent clouds.¹

The IV&V Facility is performing IV&V on the AIM spacecraft and three on-board instruments, including the Solar Occultation for Ice Experiment (SOFIE), Cloud Imaging and Particle Size (CIPS), and Cosmic Dust Experiment (CDE). To date, IV&V has completed requirements analysis efforts and has begun design analysis activities.

IV&V has identified and documented non-compliances to the NASA Software Safety Standard. These non-compliances are currently being worked on by Project and Safety personnel as part of their efforts in developing the overall Pre-Launch Safety Data Package. In addition, as part of IV&V requirements analysis efforts, IV&V has identified and documented several technical issues associated with system and software requirements which the AIM project has agreed to address.

¹“Strange Clouds” http://science.nasa.gov/headlines/y2003/18feb_nlc.htm.

For further information about AIM, visit <http://aim.hamptonu.edu/mission/1mission.html>.

AFT FLIGHT DECK (AFD)

IV&V Project Manager: Raju Raymond

IV&V Contractor: Titan

NASA’s ARIES B-757 airplane is a general purpose flying laboratory capable of supporting a variety of flight test research. The Aft Flight Deck (AFD) project involves installing a full-size cockpit that supports two crew-members in the passenger cabin of the NASA ARIES Flying Laboratory.

The purpose of AFD is to provide government and industry with an efficient means of developing and testing new technology concepts to enhance the safety, capacity, and operational needs of the ever-changing Air Traffic Control System and the National Airspace System.

IV&V has performed requirements analysis on selected software components. IV&V has started initial requirements analysis on the Research Control Interface Unit (RCIU), and submitted related findings to the project. Future work includes design, code, test, and interface analysis on the RCIU software.

IV&V has provided feedback to the project on Hazard Analysis to reduce the possibility of common undetected software errors. Based on IV&V’s analysis and input, the AFD project has been provided additional assurance that no major risks exist.

AURA MISSION

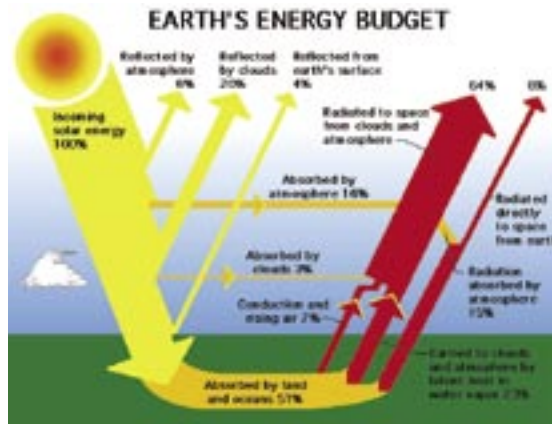
IV&V Project Manager: Marcus Fisher

IV&V Contractor: Titan

Earth Observing System (EOS) Aura is a NASA mission to study the Earth's ozone, air quality, and climate. This mission is designed to conduct research on the composition, chemistry, and dynamics of the Earth's upper and lower atmosphere employing multiple instruments on a single satellite. EOS Aura is the third in a series of major Earth-observing satellites to study the environment and climate change, and is part of NASA's Earth Science Enterprise. The first and second missions, Terra and Aqua, are designed to study the land, oceans, and the Earth's radiation budget, which represents the incoming energy from the Sun and outgoing thermal and reflected energy from the Earth. Aura's chemistry measurements will also follow up on measurements that began with NASA's

Upper Atmospheric Research Satellite and continue the record of satellite ozone data collected from the Total Ozone Mapping Spectrometer (TOMS) missions.

The IV&V team has performed analysis on the requirements, source code, and tests of the Aura spacecraft and instrument flight software. Specifically, the IV&V team verified that all software requirements were allocated to one or more test cases and that the selected verification method was appropriate. The team also verified the Spacecraft Flight Software (FSW), Microwave Limb Sounder (MLS), Ozone Monitoring Instrument (OMI), High Resolution Dynamics Limb Sounder (HIRDLS), and Tropospheric Emission Spectrometer (TES) test procedures were complete, and adequately addressed the software requirements associated with them. The team verified that Comprehensive Performance Test (CPT) procedures exercised key spacecraft and instrument functions. Through static analysis of the MLS source code, the IV&V team provided additional assurance that the software will perform reliably within the project's defined mission scenarios.



The diagram shown above illustrates incoming and outgoing energy.

The IV&V team's efforts have improved the robustness and confidence of the Aura Test Program. The program launched the spacecraft on July 15, 2004, and the spacecraft and software continue to operate nominally.

For further information about Aura, visit <http://aura.gsfc.nasa.gov/>.

BUMPER-II FOR THE NASA ENGINEERING AND SAFETY CENTER (NESC)

IV&V Project Manager: Marcus Fisher

IV&V Contractor: SAIC

The BUMPER-II system is used at the Johnson Space Center (JSC) during International Space Station (ISS) and Space Shuttle missions in order to determine the probability of either vehicle being impacted or penetrated by a meteoroid or orbital debris. The analysis code calculates the probability of no penetration (PNP) or the probability of no impact (PNI) for a spacecraft subjected to man-made orbital debris and meteoroid impacts.

The IV&V Facility is performing an independent assessment on the BUMPER-II code in order to increase the confidence in the probabilities predicted by the system.

The objectives of the IV&V effort are to assure that the software performs as intended and that there are adequate artifacts (e.g., requirements and design documents) and processes in place to support the maintenance of the system. In order to achieve these objectives, the IV&V team has performed numerous activities, including a detailed inspection of the system's Fortran 77 code.

Code inspection was used to determine if there were any latent defects and to analyze how well the code conformed to the syntax of the language. In addition, a small set of test cases were run to assure the results were as expected and to assess the uncertainty of the numerical solution.

The IV&V team has generated numerous recommendations so that the BUMPER-II code can be improved and maintained efficiently. There were specific instances where the code did not match the defined numerical solutions. For these instances, the code will be modified so it reflects the actual equations proven to predict PNP and PNI. Other recommendations dealt with improvements to the code so it conforms to a common syntax of the Fortran Language, in order to make maintenance of the system more efficient.

For further information about the NESC's work, visit <http://www.nesc.nasa.gov/>.



COSMIC RAY ENERGISTICS AND MASS BALLOON EXPERIMENT (CREAM)

IV&V Project Manager: Raju Raymond

IV&V Contractor: SAIC

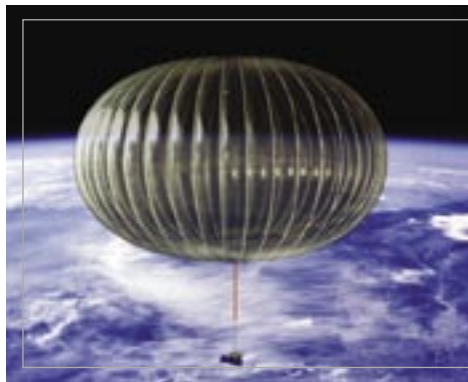
NASA's Balloon Program Office is developing new ultra long-duration balloon (ULDB) vehicle technology to conduct various experiments and scientific studies. Large unmanned balloons provide NASA with an inexpensive means to study the Earth and space and to place payloads into a space environment. The unique capabilities of this program are vital for the development of new technologies for NASA's space flight missions. The ULDB is a revolutionary research balloon designed to fly higher and longer than anything before it, which could open a new era in scientific research.

The CREAM experiment is intended to study ultra high-energy cosmic rays. The goal is to observe spectral features and/or abundance changes that might be related to a supernova acceleration limit.

V&V has performed an Independent Assessment on selected ULDB/CREAM software components and focused on the requirements and implementation of the software. IV&V has completed requirements and code analysis on the flight software, the Iridium System and the Solar Pointing System.

The IV&V team generated recommendations that were accepted by the CREAM project and incorporated into the software. Based on the issues identified by IV&V, the project developed mission operations procedures to avoid potential data corruption during flight. The CREAM mission was launched from Antarctica on December 15, 2004. The flight has broken the duration record for a long duration balloon flight.

For further information about CREAM, visit <http://www.wff.nasa.gov/~code820/missions/cream.htm>.



Shown at left is an artist's conception of CREAM attached to the ULDB.

DEMONSTRATION OF AUTONOMOUS RENDEZVOUS TECHNOLOGY (DART)

IV&V Project Manager: Peter Medley

IV&V Contractor: Titan

DART will prove the technologies required for a spacecraft to locate and rendezvous with another spacecraft without direct human guidance. While NASA has performed rendezvous and docking missions in the past, astronauts have always piloted the spacecraft. The autonomous rendezvous technologies demonstrated by DART represent a critical step for establishing an autonomous rendezvous capability for the United States and will lay the groundwork for future reusable manned and unmanned launch vehicle operations. Future applications of this technology include cargo delivery, space operations for the International Space Station (ISS), and other on-orbit activities such as satellite retrieval and servicing missions.

The DART vehicle will be launched aboard a Pegasus launch vehicle and inserted into a circular parking orbit. The vehicle will then perform a series of orbit transfers to arrive at a point near a target satellite (MUBLCOM) using state-of-the-art Global Positioning System (GPS) relative navigation techniques. Using the vehicle's main instrument, the Advanced Video Guidance Sensor (AVGS), DART will then approach the target satellite and perform a series of proximity operations including station keeping, docking axis approaches, and circumnavigation. Finally the vehicle will demonstrate a collision avoidance maneuver, then depart the vicinity and transition to its final orbit. The entire sequence will be accomplished under autonomous control.

The IV&V Facility performed IV&V on selected software components based on the DART Critical Functions List created by IV&V.

Two issues identified by IV&V, MUBLCOM attitude inconsistencies and Single Event Upset (SEU) handling, have direct impact on DART's success. The SEU issue has been the focus of recent launch attempts due to the increased solar activity in the latter parts of 2004. The impact of the MUBLCOM issues has come to the forefront after the GPS signal was interrupted only hours prior to launch at the initial launch attempt in October 2004. The GPS signal is critical to DART as it will be used for ranging purposes during rendezvous maneuvers. All the analysis and project review issues raised by IV&V were accepted by the project. DART's launch is currently estimated for early March 2005.

For further information about DART, visit <http://www.orbital.com/AdvancedSpace/DART/index.html>.

DAWN

IV&V Project Manager: Stephanie Ferguson

IV&V Contractor: Titan

Dawn's goal is to characterize the conditions and processes of the solar system's earliest epoch by investigating in detail two of the largest protoplanets remaining intact since their formations. Ceres and Vesta reside in the extensive zone between Mars and Jupiter together with many other smaller bodies, called the asteroid belt. Each has followed a very different evolutionary path constrained by the diversity of processes that operated during the first few million years of solar system evolution. The top-level question that the mission addresses is the role of size and water in determining the evolution of the planets. The science team consists of leading experts in the investigation of the rocky and icy planets using proven measurement and analysis techniques.

Dawn has much to offer, both to scientists and to the general public. It brings images of varied landscapes on previously unseen worlds to the public, including mountains, canyons, craters, lava flows, polar caps and possibly ancient lakebeds, streambeds and gullies. Students can

follow the mission over an entire K-12 experience as the mission is built, cruises to Vesta and Ceres, and returns data. The public will be able to participate through the Solar System Ambassadors and through participation on the internet.

Dawn provides context for the understanding of the observation of extra solar-planetary systems. It provides data on the role of size and water in planetary evolution, and forms a bridge between the exploration of the rocky inner solar system and the icy outer solar system. Finally, Dawn completes the first order exploration of the inner solar system, addresses NASA's goal of understanding the origin and evolution of the solar system, and complements ongoing investigations of Mercury, Earth and Mars.

The IV&V Facility began performing IV&V on selected Dawn spacecraft and Digital Control Interface Unit (DCIU) flight software components in late January. This year, IV&V performed traceability analysis on multiple levels of requirements for the On Board Computer and Uplink components. The IV&V team performed analysis and evaluation of requirements on DCIU requirements as well as analysis of requirements for the interfaces between the spacecraft and the DCIU and Framing Camera instrument. IV&V provided design analysis of the Attitude Control System and a "quick look" design review of the Fault Protection Performance Specification. IV&V analyzed DCIU code and began analysis of the Spacecraft Flight Software Test Plan and the On Board Computer Test Procedures. The team sup-



ported and participated in multiple levels of technical and milestone reviews, submitting several Requests for Action (RFA) independently and assisting on additional RFAs. IV&V also completed an analysis of the Dawn project's software development process, and provided an analysis report and details on identified issues.

Throughout our involvement, the Dawn project has been responsive to IV&V's findings. Of the technical issues identified and provided to the project thus far, over 25% of the issues have agreed-upon resolutions awaiting implementation. Based on IV&V's input, the Dawn development contractor is correcting identified issues in the Dawn Software Development Plan. As a result of IV&V's traceability analysis, the project is taking action to improve the linkage between system and software level requirements. IV&V is currently working with the project regarding updates to the Fault Protection Performance Specification based on our "quick look" findings.

For further information about Dawn, visit <http://dawn.jpl.nasa.gov/>.

ENHANCED CAUTION AND WARNING SYSTEM (ECWS)

IV&V Project Manager: Marcus Fisher

IV&V Contractor: Titan

The enhanced Caution and Warning System (eCWS) monitors the Extravehicular Mobility Unit (EMU) worn by the astronauts during spacewalks. The eCWS monitors consumables including primary and secondary oxygen, water (for cooling the astronaut) and battery power during a spacewalk. The system analyzes data and reports on the EMU's operation by presenting information on the Display and Control Module (DCM) and sounding tones in the astronaut's headset when significant events occur. The eCWS reports when critical limits are reached to allow the crew member sufficient time to get back inside safely.

The IV&V Facility conducted an Independent Assessment (IA) of the eCWS software. The purpose of this assessment was to provide International Space Station (ISS) management with an independent view of the maturity of the software products and the thoroughness of the testing. This included assessing the process used to create the software; analyzing the source code to identify potential issues; performing coverage analysis of the source code to identify code paths that are not formally tested; performing requirements-based analysis of the eCWS certification test procedures to ensure that software requirements are thoroughly verified by testing and, performing Failure Mode and Effects Analysis on the software to determine if all failure modes are tested.

The Independent Assessment Team (IAT) found that the eCWS software project was thorough, well-structured and well-managed. A significant contribution made by the IAT was the identification of out-of-range low sensor failures that the software requirements did not adequately address. Although these scenarios are remote, they could have posed risks to the safety of a crew member. The Project accepted these recommendations and updated the necessary documentation.



The photo above shows an astronaut wearing an Extravehicular Mobility Unit.

FLUID AND COMBUSTION FACILITY (FCF)

IV&V Project Manager: Tom Macaulay

IV&V Contractor: Titan

The Fluids and Combustion Facility (FCF) is a modular, multi-user facility being developed by Glenn Research Center to support microgravity fluid physics and combustion science experiments utilizing the United States Lab Module onboard the International Space Station (ISS).

Fluids and combustion experiments will be conducted within the FCF on orbit, controlled by Principal Investigators working in their laboratories and offices on the ground. Ground control is facilitated by the Telescience Support Center (TSC) located at Glenn Research Center. Astronauts onboard the ISS will be able to perform some FCF operations (setup, maintenance and troubleshooting) using a laptop computer known as the SSC (Station Support Computer). However, the primary FCF experimenters are intended to be scientists on the ground.

Thanks to the understanding of combustion processes in microgravity gained using the FCF, astronauts on orbit or en route to the Moon or Mars may be able to extinguish accidental fires more quickly, thus making long-duration space flights safer. FCF's research may lead to methods for lowering gas furnace pollution, a significant factor in atmospheric contamination. Additionally, fluid science experiments offer ways to improve commercial industrial practices and contribute to advances in public medicine and the treatment of disease.

Software plays a major role in the FCF. As most of the experiments will be conducted remotely, software is required to control and ensure the system is safe during combustion and fluid processes. An IV&V team is performing an independent assessment of the most mission-critical software components, focusing on requirements and testing. By ensuring that FCF software requirements are completely tested and inspecting the code for errors that cannot be caught by standard compilation tools, the IV&V team helps ensure that the objectives of the Fluids and Combustion Facility will be met while maintaining the safety of the astronauts.

The IV&V Facility has helped the FCF project to clarify its requirements and ensure that test procedures are accurate and complete. The IV&V team discovered three code sequences that could have led to unpredictable results. Based on IV&V's observations, the FCF project software team is reworking those code sequences, improving the safety of the system.

For further information on FCF, visit <http://fcf.grc.nasa.gov/>.

GAMMA-RAY LARGE AREA SPACE TELESCOPE (GLAST)

IV&V Project Manager: Steve Pukansky

IV&V Contractor: SAIC

The Universe is home to numerous exotic and beautiful phenomena, some of which can generate almost inconceivable amounts of energy. The Gamma-ray Large Area Space Telescope (GLAST) will open the high-energy world of black holes to exploration. With GLAST, astronomers will at long last have a superior tool to study how black holes, notorious for pulling matter in, can accelerate jets of gas outward at fantastic speeds. Physicists will be able to study subatomic particles at energies far greater than those seen in ground-based particle accelerators. Cosmologists will gain valuable information about the birth and early evolution of the Universe.

GLAST is part of the Structure and Evolution of the Universe (SEU) theme, one of four major science themes within the NASA Office of Space Science. Through the SEU program, scientists seek to explore the limits of gravity and energy in the Universe, explain the structure of the Universe, and forecast our cosmic destiny. For this unique endeavor, one that brings together the astrophysics and particle physics communities, NASA is teaming up with the U.S. Department of Energy and institutions in France, Germany, Japan, Italy and Sweden. The launch is scheduled for May of 2007.

The IV&V Facility is performing IV&V for the Spacecraft Flight Software that includes analysis activities for the Command and Data Handling (C&DH), Guidance and Control (G&C) and the Large Area Telescope (LAT).

IV&V identified a discrepancy in the definition of the conditions in which the thrusters would be commanded to enable in three operational modes. In addition, IV&V identified a discrepancy in the attitude control policy for all modes in which the thrusters could be used. The nature of this discrepancy is such that under certain conditions, the thrusters could have been improperly operated. IV&V also identified a discrepancy in how the Large Area Telescope (LAT) Flight Software (FSW) Requirement Modes and FSW Implementation Modes are addressed through FSW test. This discrepancy could have resulted in incomplete implementation and testing of LAT operational modes. The development teams have accepted these findings and are making the necessary corrections.

For further information about GLAST, visit <http://glastgsfc.nasa.gov/>.



“I’m normally a hardhead about these types of meetings, but the comments from IV&V were really good, and will improve the next version of the test plan.”

—Jack Fares

Software Responsible Engineering Authority, Spectrum Astro (GAST Project)

In addition to monitoring Earth weather, GOES will also monitor the sun's x-rays for the early detection of solar flares and other space weather.

GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITES (GOES) N-SERIES

IV&V Project Manager: Richard Grigg

IV&V Contractor: Titan

GOES, commonly called weather satellites, do more than just report on the weather. The GOES program is funded and operated by the National Oceanic and Atmospheric Administration (NOAA). The new N-series satellites, as compared to the previous series of GOES satellites, will provide more accurate location of severe storms and other weather phenomena, resulting in more precise warnings to the public. The spacecraft design and geostationary positions enable the primary sensors to 'stare' at Earth and thus frequently take images of clouds, monitor Earth's surface temperature, and sound Earth's atmosphere for its vertical temperature and water vapor distribution. Atmospheric phenomena can be tracked, ensuring real-time coverage of short-lived dynamic events such as severe local storms, and tropical hurricanes and cyclones, two types of meteorological events that directly affect public safety, property, and ultimately, economic health and development. The GOES satellites also have a search-and-rescue capability to detect distress signals from hikers, sailors and pilots.

In addition to monitoring Earth weather, GOES will also monitor the sun's x-rays for the early detection of solar flares and other space weather. This early warning is important because these solar flares affect not only the safety of humans in high-altitude missions, such as the Space Shuttle, but also military and commercial satellite communications.

The IV&V Facility has analyzed test documents and test procedures in preparation for final testing before launch.

The IV&V team also served as observers or "witnesses" on two actual tests of the software in simulated use.

The IV&V Facility helped focus attention on parts of the tests that did not work properly. These problems were then corrected by the developer before the next test. In addition, IV&V identified some ambiguities in the test documents, allowing the project to correct them, reducing the chance of errors when testing the GOES-O and GOES-P satellites.

For further information about GOES-N, visit <http://www.osd.noaa.gov/GOES/>.

HUBBLE SPACE TELESCOPE (HST)

IV&V Project Manager: Markland Benson

IV&V Contractor: SAIC

The Hubble Space Telescope is NASA's space-based cosmic observer and has been collecting data since its launch and deployment in April of 1990. Hubble is also an integral part of NASA's Origins Program, which is designed to aid us in obtaining knowledge of our solar system's roots. Hubble works around-the-clock to map the Universe by using excellent pointing precision, powerful optics, and state-of-the-art instruments to provide stunning views of the Universe that cannot be made using ground-based telescopes.

Two new instruments, the Cosmic Origins Spectrograph (COS) and the Wide Field Camera 3 (WFC3), have been developed for the Hubble Space Telescope to enhance its capabilities and extend our view of the Universe.

The IV&V Facility performed analyses on the software for COS and WFC3, focusing on the requirements and test programs of these instruments. Additionally, traceability was analyzed to gauge the completeness of the flow down of mission level requirements through instruments, software and tests.

For COS, testing was determined to provide thorough coverage of the instrument's software requirements. IV&V analysts produced a number of issues which were closed by the instrument developer, resulting in improved test documentation. For WFC3, the software test program was evaluated and was found to have software requirements that were not objectively verified. The currently unverified requirements are to be verified during integration testing of the WFC3 hardware and software. IV&V analysts determined that complete traceability did not exist from mission level requirements through instrument and software requirements to test procedures. The HST project has agreed that this traceability is needed and plans to produce it.

For further information about Hubble, visit <http://hubblesite.org/>.



The photo above shows the Hubble Space Telescope floating above Earth.

INTEGRATED FINANCIAL MANAGEMENT PROGRAM

IV&V Project Manager: Pat Callis

IV&V Contractor: Titan

Agency-wide management and improvement of financial, physical, and human resources are at the heart of the Integrated Financial Management Program (IFMP). IFMP will dramatically improve NASA's business processes and will greatly increase connectivity between Centers, which will enhance their ability to support multiple programs by sharing accounting and financial data. This will help improve employee productivity and operational efficiency, and increase NASA's fiscal and management accountability by delivering more reliable information. The IFMP will help NASA meet the President's objectives, specifically in the key areas of the President's Management Agenda: strategic management of human capital; competitive sourcing; improved financial management; and budget and performance integration.

The IV&V Facility performed an Independent Assessment (IA) on specific requirements, design documents, test coverage, application security, and risk management aspects of the IFM Program system.

IV&V accomplished the following: generated and maintained Budget Formulation (BF) requirements database, accepted and used by the project for traceability purposes; performed negative and positive security tests on user access during BF integration testing; performed risk mitigation and issues tracking analysis on the BF module Rel. 0.5B; supported Blue Print sessions for IAM project reviewing current business processes and how they fit into the SAP product; produced Requirements Traceability Report for IAM based on IV&V analyzing traceability among Level I through Level III requirements; delivered ePayroll Requirements Traceability Analysis Report documenting all levels of ePayroll requirements and requirements traceability in RequisitePro.

The BF requirements database was accepted and used by the project for traceability purposes. IV&V security tests during BF integration testing identified several security risks for which the project developed fixes.

For further information about IFMP, visit <http://ifmp.nasa.gov/>.

“The IV & V team has provided excellent support in areas of requirements traceability and quality assurance. The team is continuing to build on what the project has mapped so far by being directly involved with the Agency Process Team in analyzing and mapping Level IV requirements. The IV&V staff has always provided valuable insight to the Project Team, allowing the Project to benefit from the additional review without an impact to cost or schedule.”

—Terry Whaley
IFMP Integrated Asset Management Deputy
Project Manager

INTERNATIONAL SPACE STATION (ISS)

IV&V Project Manager: Marcus Fisher

IV&V Contractor: Titan

The ISS is NASA's space laboratory, utilizing the microgravity environment present in space as a tool to do research. This research in microgravity unmask phenomena that Earth's gravity can obscure, allowing researchers to gain useful insights into what are known as zero-g-induced occurrences that do not happen on Earth. Not only can the experiments only be done in zero gravity, those same experiments can be conducted for much longer durations than are possible aboard the Space Shuttle.

The successful work performed by the ISS IV&V team is exemplified through the receipt of numerous awards (i.e., Silver Snoopy, Flight Safety, Team Award, and Leader Award). They have been cited numerous times in Aerospace Safety Advisory Panel (ASAP) reports and have received the Space Station Program Office Team Excellence Award.

The IV&V Facility is examining the safety and mission-critical software in every US component of the ISS. This past year, the IV&V Facility has also taken on the assessment of one of the International Partner's (IP) subsystems. The IV&V team provided an assessment on the safety-critical software that resides in JAXA's (Japanese Space Agency) Centrifuge Accommodation Module (CAM).

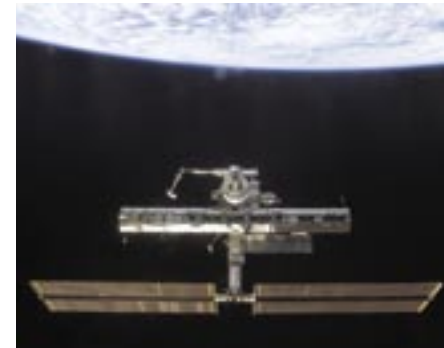
Due to the diversity of applications, wide variety of domains, and discipline expertise requirements to support the subsystems of the ISS, the IV&V ISS project is divided into nine different IV&V teams, each supporting specific ISS subsystems. Expertise is then applied synergistically, or as a combined effort, to ensure that the ISS software functions as a complete system, reliably and safely.

Before each assembly is flown into space, the IV&V Facility team performs a flight software readiness assessment. This assessment identifies the team's independent evaluation of the software readiness to support the assembly and helps determine the approval for the Certificate of Flight Readiness (CoFR).

The IV&V team continuously provides benefit to the ISS program and has been recognized by the program as the technical experts for the ISS flight software. The IV&V team has successfully worked and certified the uplink of the Guidance, Navigation & Control Release 4 (GN&C R4) system, early Portable Computer System Release 2 (ePCS R2) system, Space Integrated Global Positioning System/Inertial Navigation System Release 2 (SIGI R2) system, and the External Control Zone (ECZ) EXT Release 4 (R4) system.

Working and certifying systems for uplink requires a systematic and disciplined IV&V program. The IV&V team has developed a state-of-the-art test bed where software releases can be executed and assessed under off-nominal scenarios, giving the team several perspectives when looking for software-related issues. A significant event was discovered using this test bed that dealt with how the ISS software performs load-shedding. IV&V's independent testing uncovered hidden software behavior that would have deviated from the desired procedure for load shedding. These types of scenarios are difficult to uncover and the IV&V Space Station Test Bed is an invaluable asset in searching for such events.

For further information about the ISS, visit <http://spaceflight.nasa.gov/station/>.



JAMES WEBB SPACE TELESCOPE (JWST)

IV&V Project Manager: Frank Huy

IV&V Contractor: SAIC

The James Webb Space Telescope (JWST) is an orbiting infrared observatory that will take the place of the Hubble Space Telescope and is currently scheduled for launch in 2011. The JWST will study the Universe at the important but previously unobserved epoch of galaxy formation. It will peer through dust to witness the birth of stars and planetary systems similar to our own. Using JWST, scientists hope to get a better understanding of the intriguing dark matter problem. JWST is designed to study the earliest galaxies and some of the first stars formed after the Big Bang. These early objects have a high redshift from our vantage point, meaning that the best observations for these objects are available in the infrared. JWST's instruments will be designed to work primarily in the infrared range of the electromagnetic spectrum, with some capability in the visible range.

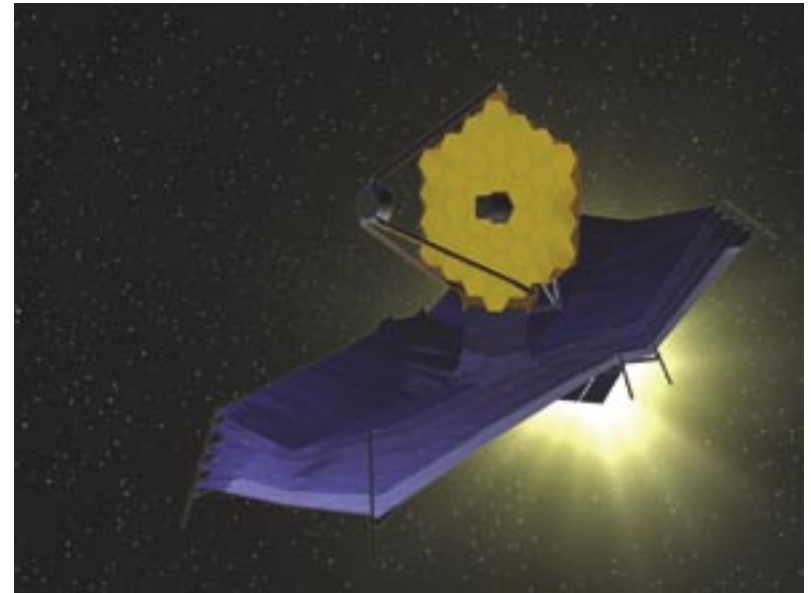
Some of the goals of the JWST mission include determining the shape of the Universe, explaining galaxy evolution, understanding the birth and formation of stars, determining how the planetary systems form and interact, determining how the Universe came to have its present chemical/elemental composition, and probing the nature of dark matter.

The IV&V Facility is performing IV&V on the Instrument Command and Data Handling (IC&DH) software. Specific analysis that IV&V has performed includes requirements and traceability analysis, code analysis and test program analysis.

In addition, the IV&V Facility is currently performing startup assessments to ascertain the level and scope of future IV&V activities for other portions of the JWST mission, including the spacecraft, Integrated Science Instrument Module (ISIM) applications and Ground Segment.

IV&V has attended both formal and informal life cycle reviews, providing an independent and objective perspective of the software development efforts and software-related products under review on JWST. The IV&V team made recommendations based on observations made during the requirements traceability analysis and code analysis activities. The JWST project has acknowledged the observations and intends to take actions according to the recommendations.

For further information about JWST, visit <http://www.jwst.nasa.gov/>.



KEPLER

IV&V Project Manager: Richard Grigg

IV&V Contractor: Titan

Kepler is a special-purpose space mission in the NASA Headquarters Discovery Program for detecting terrestrial planets around other stars—meaning rocky and Earth-size planets. When a planet passes in front of (or transits) its parent star, as seen by us, it blocks a small fraction of the light from that star. If the dimming is truly caused by a planet, then the transits must be repeatable. Observing a minimum three transits, all with a consistent period, duration, and change in brightness provides a rigorous method for discovering and confirming planets—planets even smaller than the Earth. From the brightness change, the planet size can be calculated. From the period, the orbital size can be calculated and the planet's temperature estimated. Kepler will work with earth-bound telescopes to verify the planets it discovers.

In addition to finding Earth-like planets, the Kepler mission will strive to learn about the structure and diversity of planetary systems. Some of the things we hope to learn are the size, mass, frequency, and semi-major axes of planets in or near the habitable zone of a wide variety of stars. Kepler will help us estimate the frequency and orbital distributions of planets in multiple-stellar systems. The Kepler mission also supports the objectives of the NASA Origins Space Interferometry Mission (SIM) and Terrestrial Planet Finder (TPF) Mission.

IV&V created the Critical Functions Mission List and a start-up assessment report for the Kepler project. During the year, the project went through a redesign. IV&V supported the project's efforts through participation in a Preliminary Design Review (PDR) for the new design.

IV&V has helped the Kepler project team more fully understand the process and benefits of IV&V in helping to achieve mission success. The Kepler team has requested that IV&V perform code analysis on heritage code—code “inherited” from other spacecraft missions and planned for reuse on the Kepler Mission.

For further information about Kepler, visit <http://www.lawrencehallofscience.org/kepler/>.



MARS RECONNAISSANCE ORBITER (MRO)

IV&V Project Manager: Richard Grigg

IV&V Contractor: Titan

NASA's Mars Reconnaissance Orbiter, scheduled for launch in 2005, is on a search for evidence that water persisted on the surface of Mars for a long period of time. While other Mars missions have shown that water flowed across the surface in Mars' history, it remains a mystery whether water was ever around long enough to provide a habitat for life.

In its survey of the red planet, Mars Reconnaissance Orbiter will increase tenfold the number of spots surveyed close-up. One of the Mars Reconnaissance Orbiter's cameras is the largest ever flown on a planetary mission. While previous cameras on other Mars orbiters could identify objects no smaller than a school bus, this camera will be able to spot something as small as a dinner table. That capability will also allow the Orbiter to identify obstacles like large rocks that could jeopardize the safety of future landers and rovers. Its imaging spectrometer will also be able to look at small-scale areas about five times smaller than a football field, at a scale perfect for identifying any hot springs or other small water features.

After a seven-month cruise to Mars and six months of aerobraking to reach its science orbit, Mars Reconnaissance Orbiter will seek to find out about the history of water on Mars with its science instruments. MRO will zoom in for extreme close-up photography of the Martian surface, analyze minerals, look for subsurface water, trace how much dust and water are distributed in the atmosphere, and monitor daily global weather. These studies will help determine if there are deposits of minerals that form in water over long periods of time, detect any shorelines of ancient seas and lakes, and analyze deposits placed in layers over time by flowing water. It will also help determine if the underground Martian ice discovered by the Mars Odyssey Orbiter is the top layer of a deep ice deposit or whether it is a shallow layer in equilibrium with the current atmosphere and its seasonal cycle of water vapor.

The Orbiter's telecommunications systems will establish a crucial service for future spacecraft, becoming the first link in a communications bridge back to Earth, an "interplanetary internet" that can be used by numerous international spacecraft in coming years. Testing the use of a radio frequency called Ka-band, Mars Reconnaissance Orbiter may demonstrate the potential for greater performance in communications using significantly less power.

The Orbiter also carries an experimental navigation camera. If it performs well, similar cameras placed on orbiters of the future would be able to serve as high-precision interplanetary "eyes" to guide incoming landers to precise landings on Mars, opening up exciting—but otherwise dangerous—areas of the planet to exploration.

The IV&V Facility is performing IV&V on the flight software and firmware known as Field Programmable Gate Arrays (FPGA). Specific analysis that IV&V has performed includes requirements, traceability, interface, and code analysis. As a result of our requirements analysis activities, IV&V identified some portions of the requirements that were not fully developed. The MRO project has since completed these requirements.

For further information about MRO, visit <http://mars.jpl.nasa.gov/mro/>.

**In its survey of the
red planet, Mars
Reconnaissance Orbiter
will increase tenfold
the number of spots
surveyed close-up.**

Shown at right is an artist's
conception of the MRO.



MERCURY SURFACE, SPACE ENVIRONMENT, GEOCHEMISTRY AND RANGING (MESSENGER)

IV&V Project Manager: Wes Sweetser

IV&V Contractor: Titan

The MESSENGER mission, spacecraft, and science instruments are focused on answering six of the key outstanding questions that will allow us to understand Mercury as a planet:

- Why is Mercury so dense?
- What is the geologic history of Mercury?
- What is the structure of Mercury's core?
- What is the nature of Mercury's magnetic field?
- What are the unusual materials at Mercury's poles?
- What volatiles are important at Mercury?

MESSENGER uses gravity assists from both Venus and Mercury to lower its speed relative to Mercury at orbit insertion. Three Venus flybys significantly resize and rotate the spacecraft's trajectory closer to Mercury's orbit. Two 200-kilometer (124-mile) minimum-altitude Mercury flybys, each followed about two months later by a course correction maneuver, rotate and resize MESSENGER's orbit enough to enable Mercury orbit insertion in early July 2009.

IV&V completed an independent assessment of the MESSENGER flight software system to help ensure all important requirements were satisfied and fully represented in the computer code. This work provided additional assurance that the mission will be a success.

IV&V uncovered inconsistencies in how the requirements were being implemented, which the project resolved prior to launch.

MESSENGER successfully launched August 3, 2004.

For further information about MESSENGER, visit <http://messenger.jhuapl.edu/>.

THE NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM PREPARATORY PROJECT (NPP)

IV&V Project Manager: Stephanie Ferguson

IV&V Contractor: Titan

The National Polar-Orbiting Operational Environmental Satellite System (NPOESS) will provide long-term systematic measurements of key environmental variables beginning about 2009. In preparation for this system, NASA and the Integrated Program Office are conducting a joint mission, the NPOESS Preparatory Project (NPP). NPP will provide risk reduction for this future operational system and will maintain continuity of certain environmental data sets that were initiated with NASA's Terra and Aqua satellites. NPP will launch in early 2006.

These measurements will be taken by three different sensors.

VIIRS—Visible Infrared Imaging spectro Radiometer Suite

CrIS—Crosstrack Infrared Sounder

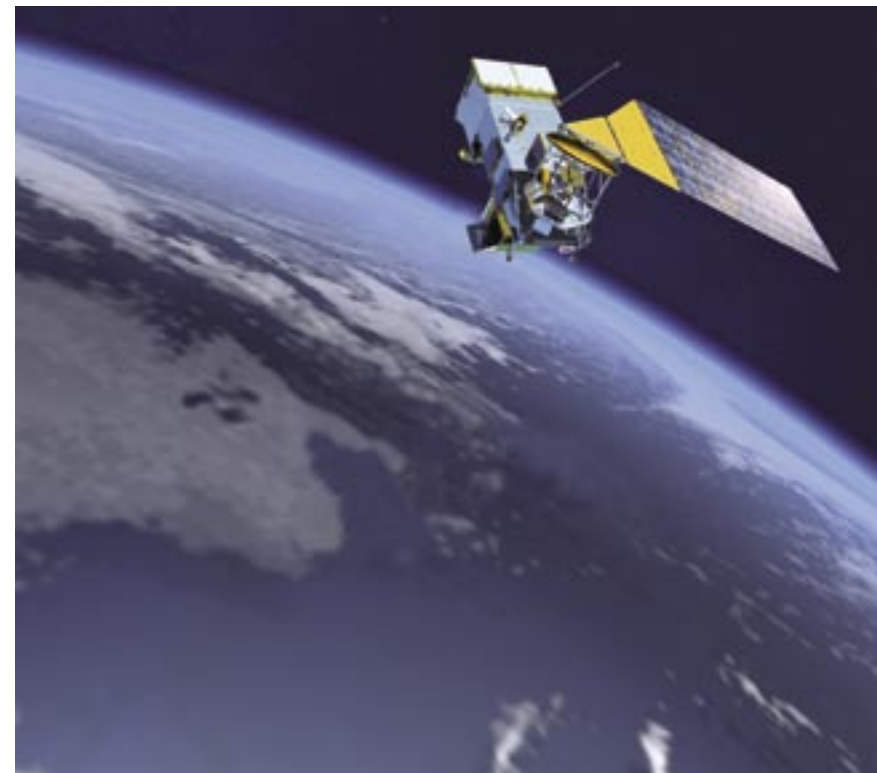
ATMS—Advanced Technology Microwave Sounder

The data collected by these sensors will be processed into sensor data records (SDRs). The SDRs are used to create environmental data records (EDRs), which are operational data products, and climate data records (CDRs) for long-term climate and global change studies.

IV&V participated in preliminary code walkthroughs. IV&V will continue to perform analysis on selected catastrophic/critical/high risk NPP spacecraft flight software components as described in the NPP Critical Functions List. The analysis includes requirements, code, test, and interface analyses, as applicable for the life cycle of the software being analyzed.

IV&V provided additional assurance by supporting code walkthroughs of portions of the Flight Software for the Spacecraft Control Computer (SCC) and Command and Data Processor (CDP). The developer has agreed to address all issues (project and IV&V) that were identified during the walkthroughs.

For further information about NPOESS, visit <http://jointmission.gsfc.nasa.gov/>.



Shown above is an artist's concept of the NPOESS satellite.

NEW HORIZONS

IV&V Project Manager: Peter Medley

IV&V Contractor: Titan

Pluto, the smallest planet, is the only planet not yet visited by a spacecraft. Discovered in 1930, it is sometimes likened to a large asteroid or comet, or even a double planet system, since its moon Charon is about half the diameter and mass of Pluto. Today it is understood that both Pluto and Charon were former inhabitants of the mysterious Kuiper Belt which resides outside the orbit of Neptune. Most of what we know about Pluto we have learned since the late 1970s from ground-based observations, the Infrared Astronomical Satellite (IRAS), and the Hubble Space Telescope. Many of the key questions about Pluto and its satellite Charon await the close-up observation of a space flight mission.

The spacecraft will use a remote sensing package that includes imaging instruments and a radio science investigation, as well as spectroscopic and other experiments, to characterize the global geology and morphology of Pluto and its moon Charon, map their surface composition, and characterize Pluto's neutral atmosphere and its escape rate.

IV&V is being performed on selected software components as described in the New Horizons Critical Functions List (CFL) Report created by IV&V. All major software subsystems of the project are being analyzed, including Guidance & Control, Command & Data Handling, Autonomy, Instrumentation, and Ground Systems. Requirements and design analysis have been completed, with code analysis and preliminary test analysis underway.

IV&V has provided feedback to the project on issues that have been identified by the analysis being performed as well as on issues raised during appropriate project reviews and walkthroughs. IV&V has also provided feedback to the project on risk management processes and associated impact.

For further information about New Horizons, visit <http://solarsystem.jpl.nasa.gov/missions/profile.cfm?Sort=Target&Target=Pluto&MCode=PKB>.

“Thanks again for helping make a large and positive impact on New Horizons.”

—Dr. Alan Stern
Principal Investigator,
New Horizons

ORBITING CARBON OBSERVATORY (OCO)

IV&V Project Manager: Wes Sweetser

IV&V Contractor: Titan

OCO will make global, space-based observations of atmospheric carbon dioxide (CO₂) with the precision, resolution, and coverage needed to significantly increase our understanding of the geographic distribution of CO₂ sources and sinks (surface fluxes) and the processes controlling their variability over the seasonal cycle.

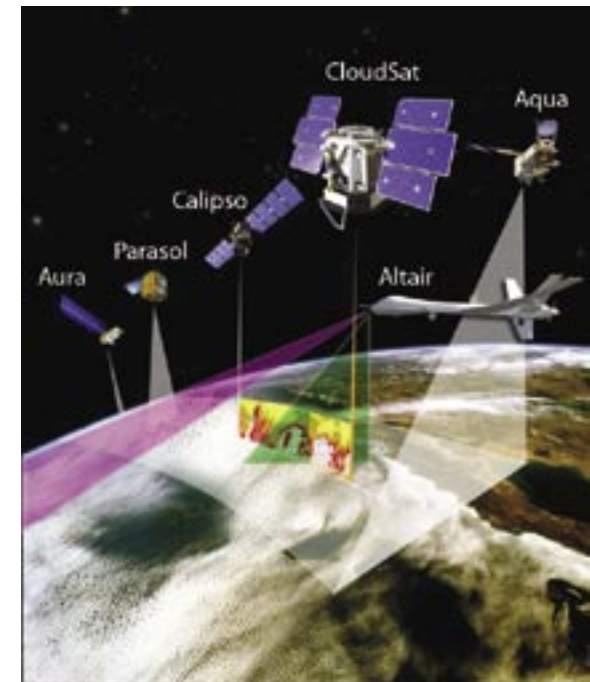
There are three mission objectives:

1. Successfully launch the OCO spacecraft into a sun-synchronous near-polar orbit that provides near global coverage at monthly intervals. The OCO orbit insertion will be synchronized with the A-Train spacecraft to maximize coordination of science observations.
2. Make space-based measurements of atmospheric O₂ and CO₂ to meet the mission goal. The measurements will be performed using an instrument that incorporates three high resolution grating spectrometers.
3. Record, calibrate, validate, publish, and archive science data records and calibrated geophysical data products in the NASA Distributed Active Archive Center for use by the scientific community.

IV&V began a start-up assessment of the OCO flight software system to determine the needed level of IV&V support for FY05-FY07.

Although the start-up assessment has just begun, the OCO project team now has a greater understanding of the importance of IV&V in helping to achieve mission success.

For further information about OCO, visit <http://oco.jpl.nasa.gov/>.



The "Afternoon Constellations" or "A-Train" consists of five satellites that fly in close proximity to provide detailed observations of the Earth's system.

PERSONAL COMPUTER GROUND OPERATIONS AEROSPACE LANGUAGE 2 (PCGOAL2)

IV&V Project Manager: Deborah Kromis

IV&V Contractor: Titan

The PCG2 system is an advisory system consisting of a set of computer platforms, network hardware and software aimed at providing increased situational awareness for Shuttle processing personnel. The PCG2 system collects, merges, and filters data from other Shuttle ground processing systems and provides it to the user for display. The PCG2 system leverages off of the existing PC GOAL Certified Data Advisory System, providing new system advisory capabilities and enhancing existing ones. The ability to understand what is going where during Space Shuttle processing or launch operations is increased through additional and enhanced system capabilities, and through

additional advisory applications and user displays that execute on the PCG2 system. The PCG2 system has no command and control capabilities, but the PCG2 software and hardware system will be certified for use on the Space Shuttle Program such that it can be used to perform advisory functions. Possible advisory functions include using the PCG2 system to verify that Space Shuttle Operational and Maintenance requirements are being met, make Launch Commit Criteria violation calls, monitor trends, or perform data analysis, system troubleshooting, and problem resolution.

The IV&V Facility began performing IV&V on the PCG2 project in 2004. During Phase 0 of the project IV&V worked informally with the project, documenting both programmatic and technical issues. IV&V now has a formal agreement with the project in place and is currently reviewing test procedures for Phase 0 and requirements for Phase I of the project.

During the past year IV&V identified several critical programmatic areas of concern. These included the lack of a software safety plan and Concept of Operations (ConOps) document. The program accepted the issues and is currently addressing them.



SOLAR DYNAMICS OBSERVATORY (SDO)

IV&V Project Manager: Thomas Robinson

IV&V Contractor: SAIC

The Solar Dynamics Observatory mission, commonly referred to as SDO, is part of NASA's "Living with a Star" program. The Sun and Earth are a connected system and solar variations directly affect Earth's magnetic fields and atmosphere. SDO will help us develop the scientific understanding of the connected Sun-Earth to address those aspects that directly affect our life and society. The basic SDO mission objectives seek answers to the questions: How and why does the Sun vary? How does the Earth respond? What are the impacts to humanity?

There are three (3) primary scientific investigations being implemented on the Solar Dynamics Observatory. The Helioseismic Magnetic Imager (HMI) will image the Sun's helioseismic and magnetic fields over the Sun's entire visible disk to help us understand the Sun's interior and magnetic activity. The Atmospheric Imaging Assembly (AIA) and Guide Telescopes (GT) will capture multiple, simultaneous, full-Sun-view high resolution images of the Sun's chromosphere and low corona over a wide range of temperatures. The Extreme Ultraviolet Variability Experiment (EVE) will measure the solar extreme ultraviolet (EUV) spectral irradiance to help us understand variations. SDO is scheduled to launch in April 2008.

The on-board software for the SDO flight avionics is critical for communications and orbit maneuvering. The SDO instrument software is critical for the successful collection of the science data throughout the mission lifetime. First, the critical flight software functions for the SDO mission were identified. Then these critical functions were ranked to establish priority. This identification and ranking process was performed for the spacecraft's main processor and subsystems, and for the instrument systems (HMI, AIA and EVE). The IV&V Facility started analysis of the SDO spacecraft and instrument flight software in March 2004. Typical IV&V efforts include requirements evaluation, traceability analysis, interface analysis, design analysis, software code analysis, and software test analysis.

A number of technical issues have been successfully worked between IV&V and the SDO project. The SDO project reports that IV&V is demonstrating real "value added" to SDO and mission assurance.

For further information on SDO, visit <http://sdo.gsfc.nasa.gov/>.

The basic SDO mission objectives

seek answers to the questions:

How and why does the Sun vary?

How does the Earth respond?

What are the impacts to humanity?

SOLAR TERRESTRIAL RELATIONS OBSERVATORY (STEREO)

IV&V Project Manager: Steve Pukansky

IV&V Contractor: SAIC

The STEREO mission will provide a new perspective on solar eruptions by imaging Coronal Mass Ejections (CMEs) and background events from two observatories simultaneously. To obtain unique views of the Sun, the twin observatories must be placed into a rather challenging orbit where they will be offset from one another. One observatory will be placed “ahead” of the Earth in its orbit and the other “behind” using a series of lunar swing-bys. Just as the slight offset between your eyes provides you with depth perception, this placement will allow the STEREO observatories to obtain 3-D images of the Sun.

The IV&V Facility is performing IV&V for the Spacecraft Flight Software (FSW) that includes analysis activities for the Command and Data Handling (C&DH), Boot, Guidance and Control (G&C) and Earth Acquisition subsystems. The team is currently planning to also support all major milestone reviews throughout the life of the project, and supported a Mission Operations Review in 2004. The IV&V team completed analysis of STEREO FSW Build 1 and code reviews on Build 2. Team focus included I553 Bus Specification; G&C and C&DH/EA code; IMU Data Manager; Digital Solar Altitude Detector (DSAD) and Thruster Wheel Data Manager; Flight GN&C Algorithm MATLAB® Models; and, the Data Collection Buffers (DCB) Package.

IV&V discovered a reaction wheel error message in the design models with incorrect values being sent to the flight software and to the ground. Under certain conditions, improper handling of the message could result in loss of control and eventual loss of spacecraft. The development team has accepted the finding and made the necessary corrections to the models so that the message is handled properly. Several software-related discrepancies and issues have been conveyed to the developer and the project management, and are currently being reviewed, resolved or mitigated. The team also participated in the Memory Object Handler and Command Macro reviews and found no significant issues, providing the STEREO project with additional assurance in those components.

For further information about STEREO, visit <http://stp.gsfc.nasa.gov/missions/stereo/stereo.htm>.

“They did indeed find a pair of bugs that
were still in the code...

Thanks IV&V!”

—Dan Wilson
STEREO Subsystem Lead

SPACE SHUTTLE

IV&V Project Manager: Melissa J. Bodeau

IV&V Contractor: Titan

The Space Shuttle is the world's first reusable spacecraft and the first spacecraft in history that can carry large satellites both to and from orbit. The Shuttle launches like a rocket, maneuvers in Earth orbit like a spacecraft, and lands like an airplane. The Space Shuttle and its software are immensely complex systems. IV&V of Shuttle software is crucial to providing the high level of safety and mission assurance necessary when human life is at stake.

Software development on the Space Shuttle can be divided into two major areas. The first area is maintenance and improvement of the existing Shuttle software that is located in its General Purpose Computers (GPC), Main Engine Controllers (MEC), and other hardware/software systems. The second area is upgrades to the Space Shuttle that add new software and replace existing software with more capable or safer systems.

IV&V is performed on all critical changes to the existing GPC and MEC software, as well as several other critical software areas. Each change is analyzed with appropriate requirements, design, code, test, and systems analysis tasks to ensure correctness of the final software and that there are no unintended consequences to the unchanged areas. During 2004, IV&V was also performed on two major Shuttle upgrades, the Cockpit Avionics Upgrade (CAU), and the Advanced Health Management System (AHMS). The CAU and AHMS software were analyzed in close coordination with the software development life cycle to help ensure the quality of the final system and to find errors when they are least costly to repair.

The IV&V Facility has been working with the Space Shuttle since 1997. In that time defects have been found that, if they had remained undetected and had manifested during flight, could have caused the loss of a crew. To this add defects found early in the software development process and IV&V has saved the Space Shuttle money and time, and has provided an increased level of confidence in Shuttle software.

For further information about the Space Shuttle, visit <http://www.nasa.gov/centers/johnson/missions/shuttle.html> or <http://spaceflight.nasa.gov/shuttle/>.



Shown above is liftoff of the Space Shuttle Endeavour.

SPACE TECHNOLOGY 5 (ST-5)

IV&V Project Manager: Wes Sweetser

IV&V Contractor: SAIC

The New Millennium Program's (NMP) ST-5 will launch multiple miniature spacecraft, called nanosats or small-sats, to test innovative concepts and technologies in the harsh environment of space. During flight validation of its technologies, ST-5 may measure the effect of solar activity on the Earth's magnetosphere, the region of upper atmosphere that surrounds our planet. ST-5's objective is to demonstrate and flight-qualify innovative technologies and concepts for application to future space missions.

The IV&V Facility completed an independent assessment of the ST-5 mission, with particular emphasis this year on providing an independent review of the requirements verification test matrix to ensure that all software requirements on the program have been appropriately traced, reviewing the formal software acceptance test procedures, and participating at the software test readiness review.

The analysis efforts performed by IV&V have provided the ST-5 project with additional assurance that no major issues or identified risks exist.

For further information about ST-5, visit <http://nmp.jpl.nasa.gov/st5/st5-index.html>.

SWIFT

IV&V Project Manager: Christina Moats

IV&V Contractor: Titan

Gamma-ray bursts (GRBs) are the most powerful explosions the Universe has seen since the Big Bang. Approximately twice a week, satellites detect one of these brief, intense flashes of gamma radiation. They come from all different directions of the sky and last from a few milliseconds to a few hundred seconds. So far, scientists do not know what causes them.

With Swift, scientists will have a tool dedicated to solving the gamma-ray burst mystery. Swift's three instruments will give scientists the ability to scrutinize gamma-ray bursts like never before. Within seconds of detecting a burst, Swift will relay a burst's location to ground stations, allowing both ground-based and space-based telescopes around the world the opportunity to observe the burst's afterglow.

Swift, a NASA mission with international participation, launched on November 20, 2004. IV&V conducted assessments of draft and final Swift project documentation, products and processes. IV&V ensured that the assessments were at the appropriate level required to support the current development phase and software maturity. Additionally, IV&V participated in formal project reviews, including project level reviews of system concepts and requirements, system designs, system software requirements and designs, code, test planning and execution, and operational readiness for software.



Swift at the Kennedy Space Center undergoing pre-launch preparations.

IV&V identified errors in instrument flight software that would lead to corrupted data and unintended processor resets. IV&V also identified a lack of traceability from spacecraft attitude control subsystem (ACS) requirements to tests, which would have left the correctness of the ACS implementation uncertain. In addition, IV&V identified an error in a stored command sequence that would prevent Swift from collecting science data until a ground controller forced a manual reset. Each of these IV&V findings was addressed by the Swift project, improving the quality of the Swift software and the opportunity for mission success. IV&V also identified areas which maintainers or future projects using the Swift software are likely to find problematic, and where additional documentation, review, and development will be needed.

For further information about Swift, visit <http://swift.gsfc.nasa.gov/docs/swift/swiftsc.html> or <http://www.swift.psu.edu/>.

THEMIS (TIME HISTORY OF EVENTS AND MACROSCALE INTERACTIONS DURING SUBSTORMS)

IV&V Project Manager: Judi Connelly

IV&V Contractor: SAIC

The THEMIS mission, scheduled for launch in 2006, will study the onset and evolution of Magnetospheric Substorms. Five probes will be deployed throughout the Earth's Magnetic Field. The probes will coordinate with 20 ground stations to measure the solar wind interacting with the magnetic field producing the onset of Northern Auroral storms. The result will answer 30-year-old questions in Magnetospheric Physics, such as: How does the Earth's magnetosphere process solar wind energy? What is the delineation between the cause and effect of main substorm processes? The answers to these questions are important for understanding the dynamics of the Sun-Earth Environment. The results of this mission will provide a better understanding of the Sun-Earth environment in which our communication and science satellites operate.

The flight software for instruments and flight avionics is critical for the successful collection of science data as well as various orbit maneuvering required throughout the mission lifetime. Critical Flight Software functions were identified in each of three main subsystems: Instrument Data Processing Unit (IDPU), Bus Avionics Unit (BAU) and Attitude Control component of the Ground System. IV&V has completed requirements and design analysis on two major systems (BAU and IDPU) and is currently performing code analysis on both systems. The Ground System assessment is underway and will be completed in early 2005.

IV&V has provided feedback to the project on Configuration Management processes and their associated impact. The THEMIS project was receptive and responsive to IV&V input. Technical issues identified in the BAU and IDPU components continue to be worked through to verification. In each phase of the analysis, IV&V has also reported positive observations and findings to the THEMIS project team.

For further information about THEMIS, visit http://sprg.ssl.berkeley.edu/themis/Flash/THEMIS_flash.htm.

X-37 PROJECT

IV&V Project Manager: Wes Sweetser

IV&V Contractor: Titan

NASA's X-37 is a reusable launch vehicle designed to operate in both the orbital and reentry phases of flight. The advanced technology flight demonstrator will operate at speeds up to Mach 25. The X-37 will demonstrate dozens of advanced airframe, avionics, and operations technologies that can support various launch vehicle and spacecraft designs. A major focus of the X-37 is improved thermal protection systems.

The X-37 is capable of being ferried into orbit by the Space Shuttle or an expendable launch vehicle. After it is deployed, it will remain in orbit up to 21 days, performing a variety of experiments before reentering the atmosphere and landing on a conventional runway.

The IV&V Facility completed an independent assessment of the X-37 project which included performing requirements, design, code, and test analyses on the critical software of this demonstration vehicle. IV&V was particularly focused on the guidance, navigation and control (GN&C) functions. These functions must perform a role similar to the GN&C of the Space Shuttle. These complex software routines control the X-37 as it reenters the atmosphere, glides, and lands on the runway.

The X-37 project has undergone several iterations of rescoping and replanning to meet changing NASA and national needs. IV&V has helped the project team during these iterations by providing a constant source of software expertise and guidance to ensure eventual mission success. IV&V has helped the project identify and understand several software risks, and assisted with appropriate mitigation strategies. The X-37 IV&V team has several decades of combined Space Shuttle experience, and this experience has been valuable in identifying critical software and detecting defects in X-37 software.

For further information about X-37, visit <http://spacelink.nasa.gov/NASA.Projects/Aerospace.Technology/Research.Aircraft/X-37/>.

X-43C PROJECT

IV&V Project Manager: Christina Moats

IV&V Contractor: Titan

NASA's Langley Research Center (LaRC) is leading a combined U.S. Air Force/industry team in the design and development of the X-43C demonstrator vehicle and its propulsion system. The project has developed a non-rocket, air-breathing scramjet engine. The propulsion is designed to power a vehicle in flight at hypersonic speeds up to seven times the speed of sound. When fully developed, the sophisticated X-43C technology will offer increased safety, payload capacity and economy of operation for future reusable space access vehicles.

IV&V has performed review of the project Software Development Plans (SDP) to ensure compliance to project standards and adequacy of software development processes, and provided related findings to the project.

IV&V's support in 2004 was limited as the project transitioned to a Langley "in-house" activity. IV&V analysis identified two risks regarding vendors: one related to processes and one related to tools used to manage requirements. The project accepted all recommendations from IV&V.



Shown above is an artist's conception of the X-43C.



Ensuring that our customers' safety and mission critical software meets all requirements for safety, reliability and availability; **performing leading-edge research that improves IV&V and software assurance methods, practices and tools**; participating in the vitality of the community, as well as engaging the public in the experience and benefits of exploration and discovery.



PILLAR II: RESEARCH

Goal: Be internationally acknowledged for leading and conducting research that directly contributes to higher software assurance and improved IV&V practices.

The comprehensive research supported by the IV&V Facility under the Office of Safety and Mission Assurance (OSMA) seeks to discover and develop the best tools and methods for improving mission assurance. Over the past ten years the Facility's research has transitioned into common practice and set new standards of excellence. IV&V's research portfolio included over 43 initiatives in 2004—an impressive body of work that reflects well upon OSMA, the Facility and its many collaborating institutions.

The goal of research in the area of software assurance is to evaluate more of the critical software more thoroughly and more efficiently. The intention of the research is not to automate everything, but to enable highly skilled analysts to focus their efforts. There is so much code and so little time that it has become ever more urgent to employ intelligent programs effectively. The missions NASA undertakes are difficult at best, requiring the invention of new ways to keep pace with the science required to fulfill NASA's mission of discovery and exploration. The software NASA relies on keeps evolving as well. For those whose job it is to verify that the software works as it should, the tools we use have to keep pace with the software we validate. For this reason, the IV&V Facility is involved with two major research efforts, the NASA-wide Software Assurance Research Program (SARP) and Facility Research Initiatives that focus on areas of particular interest to the IV&V Facility. The IV&V Facility encourages research which can be applied to NASA projects.

OSMA sponsors the Software Assurance Research Program (SARP). This NASA-wide research program's purpose is to provide NASA with the software assurance practices, methods, and tools needed to produce safe and reliable software. This program is designed to address fundamental software assurance problems in the field of software engineering, primarily as it relates to software safety, quality, verification and validation (V&V), testability, and reliability. This research program is intended to develop better tools, methods, and techniques for assuring software quality and to transfer proven improvements to NASA projects. SARP, managed by the IV&V Facility for OSMA, oversees research across NASA Centers, universities, and private corporations.

The Facility Research Initiatives are internally funded and selected to advance the effort to keep pace with developing technology and to find more effective ways to conduct IV&V. Many, but not all, of these research needs are addressed in the SARP, but as the SARP seeks to serve all of NASA, IV&V Project Managers sometimes require research that is designed to address very specific problems. Therefore, the IV&V Facility prioritizes its research requirements and initiates research accordingly. The potential for the transfer of the technology into practice is a leading factor in the selection and evaluation of research. The IV&V Facility monitors, encourages, and facilitates the use of real NASA data and the transition of cutting-edge research tools and practices to a NASA project. Opportunities for transition can also be funded as discrete research projects.

To further technology transfer, the Facility implemented two initiatives: the SARP Results Web Site, and the Software Assurance Symposium. In addition to researchers' publications in major academic journals, these IV&V Facility initiatives were designed to make our research known to the software development and software assurance community.

The SARP Results Web Site (SRWS) is a recent effort by the IV&V Facility to ensure greater availability of research results. It is the

repository for NASA-sponsored research that has the potential to make a significant impact in the professional field and has been officially cleared for public release. To view the software research results produced by NASA's SARP, please visit <http://sarpresearch.ivv.nasa.gov>. This site receives over 6,500 hits a month from government, industry, and academic addresses from both within the U.S. and abroad. Note that research discussed in this report includes links to the relevant portions of the SRWS. Initiative descriptions that do not include a link may indicate that the initiative is still too new to have produced publishable results, or that the results have not been cleared for release.

The other mechanism for publishing the results of SARP research is the Software Assurance Symposium (SAS) hosted by the IV&V Facility and sponsored by the Office of Safety and Mission Assurance. In its fourth year, the SAS is attended by people across government, industry, and academia who have an investment in software assurance. As a main venue for presentation of research predicated on large, safety and mission-critical systems, it is a well attended and important showcase for the research we value.

Center and University Initiatives presented at the annual Software Assurance Symposium can be found at <http://sas.ivv.nasa.gov/conclusion2004.html>.

Pillar II: Research

Initiatives



ANALYSIS & TEST OF REAL-TIME LINUX OPERATING SYSTEMS

PI: Kalynda Berens – SAIC

Government POC: Cynthia Calhoun – GRC

Period of Performance: 10/01 - 12/04

SARP Results:

<http://sarpresults.ivv.nasa.gov/ViewResearch/7.jsp>

In an era of reduced budgets, many projects are considering versions of the Linux operating system to lower cost. Some of these versions are modified to operate in a real-time and embedded environment. However, the safety, reliability, and applicability of these operating systems have not been thoroughly categorized. The objective of this research was to characterize 3 to 5 real-time Linux operating systems from a safety, reliability, and applicability perspective. This includes determining the strengths and weaknesses of the various operating systems, cataloging their error and fault, and performing functional analysis and testing to compare the Linux operating systems with the VxWorks operating system.

WHY VERIFICATION AND VALIDATION IS DIFFICULT

Imagine that it takes a minute to check a line of code and determine if it will work as intended. If that is the case, an analyst could check 60 lines of code an hour, 480 lines of code a day, and 124,800 lines in a year. That may sound like a lot, but consider that the word processing program you use may contain 10 times that many lines of code. However, if that word processing document crashes, the worst that will happen is that you might lose a little data. However, if NASA's safety and mission-critical software fails, NASA could lose science, a spacecraft, or a crew. Even though the teams who build the products that help NASA explore the Universe have their own dedicated quality assurance teams, when the stakes are high IV&V works with the projects to provide additional experience, expertise, and assurance that things will work as they should.

BAYESIAN VERIFICATION & VALIDATION TOOLS FOR ADAPTIVE SYSTEMS

PI: Johann Schumann – USRA/RIACS

Government POC: Michael Lowry – ARC

Period of Performance: 01/04 - 12/06

Reliable operation in a complex, changing, and uncertain environment is an important requirement for NASA missions. Changing conditions during the mission prohibit an accurate estimation of the system behavior during design phase. Here, adaptive control architectures (e.g., with neural networks) are applied. The research is developing and maturing a V&V software process, as well as tools for performance analysis of adaptive systems, which will make sure that any action of the system under changing conditions is safe and accurate. Its focus is on a Bayesian approach that provides probabilistic estimates about the system performance and a safe operation envelope. These V&V and monitoring tools will be evaluated in NASA-relevant case studies. Safety is a major priority in all NASA missions. One way to increase reliability is to ensure that any action taken is safe and accurate in the current state of the system, e.g., by using an adaptive controller. The

factor limiting the use of adaptive systems is the inability to provide a theoretically sound and practical V&V approach. Techniques and tools are being developed through this research with the ultimate aim of guaranteeing system robustness for a wide variety of NASA missions. Tools are being developed for V&V, analysis, and monitoring purposes to enable the estimation of control system/model performance, safety envelope, and accuracy.

COMPLETING THE LOOP: LINKING SOFTWARE FEATURES TO FAILURE

PI: Paul Garnett – MSIS

Government POC: Raju Raymond – IV&V

Period of Performance: 07/03 - 07/06

SARP Results:

<http://sarpresults.ivv.nasa.gov/ViewResearch/10.jsp>

It is not known how software features can predict software failures and defects. NASA has tools to identify system features, and the NASA IV&V Facility has a database of system defects and failures. Now what needs to be done is to link these two pieces; to link the defects with system features and provide this information in a form that can be used by machine learning tools to show how features can predict faults. Therefore, the goal has been to develop tools and methods to integrate system analysis tools and defect tracking tools to create a missing link between software features and failures. The hypothesis is that by integrating the output from software analysis tools and defect tracking tools, and then applying machine learning to the results, NASA will be able to find the predictors leading to software faults.

CONTINGENCY SOFTWARE IN AUTONOMOUS SYSTEMS

PI: Robyn Lutz and Stacy Nelson JPL/Nelson Consulting

Government POC: Allen Nikora – JPL

Period of Performance: 01/04 - 01/07

The need for autonomous agents, like the Mars Rovers, will increase as NASA fulfills the new exploration objectives. But these new autonomous vehicles such as rotorcraft and spacecraft operate in harsh environments with limited capacity to mitigate failures. Currently, when a failure occurs, vehicles may switch to a safe mode while ground crews devise a solution. Solutions are difficult because failures are hard to pinpoint and contingencies may be too complex, novel, or high-risk for current autonomous software. This work will 1) enhance diagnostic techniques to identify failures; 2) provide software contingency planning to mitigate failures; 3) perform tool-based verification of contingency software; and 4) investigate contingencies in safely relinquishing control to autonomous controllers. Results, applied to current NASA programs, will pave the way to more resilient, adaptive unmanned systems.



EMPIRICAL ASSURANCE OF EMBEDDED SOFTWARE USING REALISTIC SIMULATED FAILURE MODES

PI: Ted Bennett and Paul Wennberg – Triakis Corporation

Government POC: Phillip Merritt – IV&V

Period of Performance: 01/04 - 12/06

Reliance on analysis alone to evaluate the effect of failure modes, un-testable in an integration lab setup, will not fully mitigate the added risks due to ever-increasing system complexities and the use of intelligent behavior in software designs. Evaluating system behavior through dynamic testing in its native target environment is the best method of verification; however, this is rarely feasible for NASA space hardware. This research will simulate the NASA Mini-AER-Cam nanosatellite, running its unmodified software in its orbital environment. It will demonstrate how a high-fidelity virtual environment simulation can be used for thorough empirical assessment of system and software behavior in response to a wide range of enhanced system and component failure conditions.

FORMAL APPROCHES TO SWARM TECHNOLOGIES

PI: Christopher Rouff – SAIC

Government POC: Walt Truskowski – GSFC

Period of Performance: 02/02 - 12/05

Autonomous swarms of satellites are being proposed for missions that have complex behaviors and interactions. A significant challenge when dealing with swarms of interacting agents is how to determine that the possible exponential interactions and emergent behaviors are producing the desired results. Assuring correct behavior

and interactions of swarms will be critical to mission success. The research hypothesis is that one or more formal methods are needed to assure the correct behavior of the interactions and emergent properties of satellite swarms. Formal methods are proven approaches for assuring the correct operation of complex interacting systems. The objective of this project has been to research several formal method techniques to determine the best methods to use for assuring swarms.

IV&V COST ESTIMATION-A JOINT NASA & US NAVY COLLABORATION TO MODEL & AUTOMATE

PI: Hugh Smith – CDI Corporation

Government POC: Thomas Robinson – IV&V

Period of Performance: 02/02 - 12/05

SARP Results:

<http://sarpresults.ivv.nasa.gov/ViewResearch/21.jsp>

Anyone who has ever undertaken a home improvement project can understand both the necessity and the difficulty of estimating the associated costs. Now consider the difficulty of estimating a larger, more difficult undertaking. The requirement for Independent Verification and Validation (IV&V) of NASA software-intensive systems has increased significantly over the last decade. Because each NASA mission is unique, the preparation of estimates and budgets for a project that may last more than seven years can be difficult and time-consuming. This applied research, which draws on techniques developed and refined by the Naval Air Systems Command and applies them to the NASA software IV&V domain, is focused on improving the speed, accuracy, and consistency of IV&V project technical effort/cost estimating.

INJECTING FAULTS FOR SOFTWARE ERROR EVALUATION

PI: Kalynda Berens – SAIC

Government POC: Cynthia Calhoun – GRC

Period of Performance: 10/00 - 12/04

SARP Results:

<http://sarpresults.ivv.nasa.gov/ViewResearch/16.jsp>

Complex software is an integral part of many NASA projects. Mission assurance requires that the software must be fault/failure tolerant. New techniques are needed by IV&V to verify the fault tolerance/safety of complex software systems. Standard software testing cannot test every combination of path/input variable in a program, as this could take longer than the entire life of the Universe for many programs. Verification of acceptable behavior in the face of errors (bad sensor readings, human input errors, or other anomalies) is part of a good testing program. Independent verification usually requires intimate knowledge of the source code (which is time consuming, difficult to achieve, and expensive) or reliance on the project software development team for help (not a truly independent approach) to accomplish. Software Fault Injection is a fairly new family of techniques developed in the last decade. SFI inputs errors (real-world anomalies) into the software at various locations and verifies that the program responds in an acceptable manner. It is a collection of methods to determine where to inject the errors and how to instrument the software to verify acceptable behavior. It is traditionally used where the source code is available. It can also be used when all or part of the source code is unavailable (e.g. COTS software components or operating systems).

IV&V TECHNIQUE FOR OBJECT- ORIENTED SOFTWARE SYSTEMS

PI: Khalid Lateef – Titan Corporation

Government POC: Melissa Bodeau – IV&V

Period of Performance: 10/02 - 12/05

SARP Results:

<http://sarpresults.ivv.nasa.gov/ViewResearch/52.jsp>

NASA has considerable experience applying Independent Verification and Validation (IV&V) to traditional function-based software development programs. However, NASA's use of object-oriented (OO) techniques for the development of mission-critical software systems continues to increase. The emerging use of OO necessitates the need to establish and prove the IV&V techniques best suited for the unique challenges and risks of OO software development. The shift from the traditional function-based development to OO development, while capable of providing advantages for the development and maintenance of a system, introduces a unique set of life cycle risks. This study seeks to identify and evaluate the analysis techniques best suited for independent verification and validation of NASA systems developed using an OO approach.

INTEGRATED SOFTWARE INTO PROBABILISTIC RISK ASSESSMENT

PI: Carol Smidts – University of Maryland

Government POC: Judith Connelly – IV&V

Period of Performance: 10/00 - 01/06

SARP Results:

<http://sarpresults.ivv.nasa.gov/ViewResearch/18.jsp>

Probabilistic Risk Assessment (PRA) is a technique to assess the probability of failure or success of a mission. Current PRA neglects the contribution of software to the risk of mission failure. This research extends current PRA methodology to integrate software in the risk assessment process. The approach will be applied in new space telescope software. The research team has been able to develop techniques necessary for the systematic integration of software in PRA and has made advances toward proving the conceptual validity of the methodology on a specific subsystem of a project that is currently in development.

LAG

Any parent automatically understands the idea of lag; you send a message to do homework and often a significant amount of time may pass before the message appears to be received. Similarly, when scientists at the Jet Propulsion Labs sent commands to the Rovers on Mars, they often had to wait 25 minutes for those commands to be received and acted on. Transfer time varies constantly as both planets move in their respective orbits around the Sun. Move further out and the time lags increase dramatically; a radio signal beamed to Pluto takes at least six hours to get there. The idea of lag, and that a craft will be out of touch with ground control for long periods of time, helps explain why autonomous crafts are more and more necessary.

MODEL CHECKING ARTIFICIAL INTELLIGENCE-BASED PLANNERS

PI: Allen Nikora – JPL

Government POC: Allen Nikora – JPL

Period of Performance: 10/03 - 12/06

The goal of this ongoing research is to explore the suitability of logic model checking, and specifically, the suitability of the model checking tool SPIN to test Artificial Intelligence (AI) planning engines. AI planners are an enabling technology for autonomous control of spacecraft such as the Mars rovers. Verification must ensure that the software will not endanger the mission under any circumstances. Traditional software testing samples a small subset of conditions that the AI planner will encounter. What is needed is a testing method that checks every possible combination of conditions under well thought-out assumptions. Model checking is one such technique, and has been applied successfully to industrial projects to exhaustively test the correctness of critical software components; this research now tests these techniques in the NASA domain.

OPTIMIZING IV&V BENEFITS USING SIMULATION

PI: David Raffo – Portland State University

Government POC: Thomas E. Robinson – IV&V

Period of Performance: 10/02 - 09/05

SARP Results: <http://sarpresults.ivv.nasa.gov/ViewResearch/51.jsp>

There is never enough time or money to check every line of code in a project. The purpose of this research has been to develop a means to improve decision-making about how to determine and optimize the economic benefit of

V&V technologies. As an analogy, consider buying a pen and buying a car. The low cost of buying a pen coupled with the minimal consequences of it failing make the idea of spending extra for a warranty silly. Now consider buying a car; it's a different situation. Now consider buying a car with a warranty that promised that nothing would fail—ever. How much would that cost? How much would that be worth? How would you decide? While performing V&V on software is not exactly a warranty, doing it does increase confidence in the code. So because this research looks at how to determine the cost and benefit of doing V&V in different ways and at different times, it will enable better planning and allocation of scarce resources.

PRACTICAL MODEL CHECKING TO ENFORCE DOMAIN-SPECIFIC INTERFACES AND REQUIREMENTS

PI: Michael Beims – SIAC

Government POC: Jerry Sims – IV&V

Period of Performance: 01/04 - 01/07

Domain-specific interfaces and requirements must be checked to ensure the integrity of complex software systems. Today, checking requirements is very time-intensive and expensive because most of it must be done manually. Most error-finding tools are neither powerful enough nor customizable enough to check complicated interface rules. The SPIN model checker only works on finite state machine systems, not C/C++ code. In contrast, push-down model checking is naturally suited to checking C/C++ code because of its stack-based nature. This initiative explores the use of push-down model-checking technology to automate the checking of domain-specific NASA requirements.

PROGRAM MODEL CHECKING CASE STUDIES AND PRACTITIONER'S GUIDE

PI: John Penix – ARC

Government POC: John Penix – ARC

Period of Performance: 01/04 - 12/06

Program model checking is a verification methodology that uses state-space exploration to evaluate large numbers of potential program behaviors (executions). It can be effective at detecting critical software errors that are difficult to find through testing. While best practices for applying program model checking are emerging, they remain an ad hoc combination of methods for capturing properties, building special purpose test drivers, and modification and abstraction of application code. Also, the effect of design practice on verifiability (including model checking) has not been explored. The goal of this research is to assemble these best practices, demonstrate and validate their use in several case studies, and document the results into a Practitioner's Guide for Program Model Checking.

REDUCING SOFTWARE SECURITY RISK THROUGH AN INTEGRATED APPROACH

PI: David Gilliam – JPL

Government POC: Allen Nikora – JPL

Period of Performance: 11/00 - 12/05

A recent report on NASA's Information Technology (IT) security posture points to numerous security vulnerabilities in NASA systems. The source of security weakness is usually traced to poor software development practices, non-secure links between computing systems and applications, and mis-configurations. An otherwise secure system can be compromised easily if system or application

software on it or on a linked system has vulnerabilities. Currently, there are relatively few Security Assessment Tools (SATs) or instruments in the software development and maintenance life cycle that can help mitigate these vulnerabilities. Development and use of a Software Security Assessment Instrument (SSAI) will aid in assuring the security of NASA's software and systems. This effort has focused on the use of a formal analytical approach for integrating security into existing and emerging practices to enable development of a security assessment instrument consisting of tools, procedures and instruments that support the development of secure software. The results of this research are being studied by the NASA Office of the Chief Information Officer and the Department of Homeland Security.

REQUIREMENTS DECOMPOSITION ANALYSIS

PI: Martin Feather – JPL

Government POC: Allen Nikora – JPL

Period of Performance: 10/02 - 12/04

Requirements play a pivotal role in planning, selection, development, testing and operation of NASA's missions. Starting from mission objectives, requirements are successively decomposed. The correctness of this decomposition is critical, yet V&V of this crucial step is limited to manual inspection and pointwise testing, which are cumbersome and fallible (e.g., Mars Polar Lander). Rigorous lightweight analysis methods for requirements decomposition have been developed by the software engineering research community, and have shown promise in successful application to critical systems (e.g., rail transportation). The research-

ers have studied the application of these methods to the V&V of spacecraft software requirements, to ascertain if, when, and how they are suitable for use by NASA.

SEMANTIC METRICS FOR OBJECTIVE-ORIENTED DESIGN

PI: Letha Etzkorn – University of Alabama

Government POC: Philip Merritt – IV&V

Period of Performance: 10/02 - 12/05

SARP Results:

<http://sarpresults.ivv.nasa.gov/ViewResearch/26.jsp>

The purpose of this proposal has been to research a new suite of object-oriented (OO) software metrics called semantic metrics that have the potential to help software engineers identify fragile, low quality code sections much earlier in the development cycle than is possible with traditional OO metrics. With earlier and better fault detection, software maintenance will be less time-consuming and expensive, and software reusability will be improved. Because it is less costly to correct faults found earlier than to correct faults found later in the software life cycle, the overall cost of software development will be reduced. Semantic metrics can be derived from the knowledge-base of a program understanding system. A program understanding system is designed to understand a software module. Once understanding is complete, the knowledge-base contains digested information about the software module. Various semantic metrics can be collected on the knowledge-base. This new kind of metric measures domain complexity, or the relationship of the software to its application domain, rather than implementation complexity, which is what traditional software metrics measure. A semantic metric will thus map much more closely to qualities humans are

interested in, such as cohesion and maintainability, than is possible using traditional metrics that are calculated using only syntactic aspects of software.

SOFTWARE ASSURANCE OF WEB-BASED APPLICATIONS

PI: Tim Kurtz – SAIC

Government POC: Cynthia Calhoun – GRC

Period of Performance: 10/01 - 09/04

Currently the internet is being populated with web sites that do more than simply display static information; NASA is embracing the use of web-based applications to monitor and control space experiments. Internet commercialization has lead to the development of software assurance practices that ensure proper operation of web-based applications. Has NASA adopted the same philosophy? The objective of this research was to identify and document software assurance practices for web-based applications in use commercially and/or by NASA; identify weaknesses in NASA's web-based software assurance activities, and compile best practices guidance for use by the NASA software development, assurance and IV&V community.

SOFTWARE ENGINEERING RESEARCH/DEVELOPER COLLABORATIONS

PI: Tom Pressburger – ARC

Government POC: Tom Pressburger – ARC

Period of Performance: 01/04 - 12/07

The challenge addressed by this research initiative is the technology infusion process within NASA, particularly, the difficulty of moving new research from theory to practice. This initiative addresses that difficulty and provides an

efficient mechanism for software engineering researchers to find partner software developers for collaborations. The NASA Software Engineering Initiative Research Infusion subgroup is an initiative to infuse NASA-developed software engineering research as well as other software engineering tools and technology into use within NASA.

SOFTWARE SAFETY ASSURANCE OF PROGRAMMABLE LOGIC

PI: Kalynda Berens – SAIC

Government POC: Cynthia Calhoun – GRC

Period of Performance: 10/01 - 12/04

SARP Results:

<http://sarpresults.ivv.nasa.gov/ViewResearch/29.jsp>

Programmable Logic (PLC, FPGA, ASIC) devices are hybrids—hardware devices that are designed and programmed like software. As such, they fall in an assurance gray area. Programmable Logic is usually tested and verified as hardware, and the software aspects are ignored, potentially leading to safety and mission success concerns. The objective of this research is to first determine where and how Programmable Logic (PL) is used within NASA and document the current methods of assurance; and with that information, perform a gap analysis between NASA practices and industry/military standards and practices; and prepare training material for NASA assurance personnel and engineers on the assurance of Programmable Logic devices. The research will inform a training course made available to NASA personnel in 2005.

SYSTEM AND SOFTWARE RELIABILITY

PI: Dolores Wallace – GSFC

Government POC: Al Gallo – GSFC

Period of Performance: 01/03 - 12/04

Within the last decade better reliability models for hardware, software, and systems than those currently used have been theorized and developed but not implemented in practice. Previous research on software reliability has shown that while some existing software reliability models are practical, they are not accurate enough. New paradigms of development (e.g., OO) have appeared, and associated reliability models have been proposed but not investigated. Hardware models have been extensively investigated but not integrated into a system framework. System reliability modeling is the weakest of the three. NASA engineers need better methods and tools to demonstrate that their products meet NASA requirements for reliability measurement.

TANDEM EXPERIMENTS IN FINDING FAULTS DURING MODEL-BASED DEVELOPMENT

PI: Kurt Woodham – Titan Corporation

Government POC: Aaron Wilson – IV&V

Period of Performance: 01/04 - 12/06

Model-based development centers the software development effort on models of the intended software behavior and relies on code generation to produce the production software. Unfortunately, existing V&V analysis processes and tools do not readily accommodate models that contain numeric data variables involved in interrelated constraints; for example, most control models expressed in languages

such as Simulink® and SCADE. Such models are being used increasingly for NASA missions such as STEREO. New analysis methods and an expanded V&V toolset are required to effectively perform V&V on flight-critical software developed using such models. The effectiveness of existing V&V methods when data variables are present is currently very limited. This project aims at developing and empirically assessing alternatives to existing techniques.

TRANSITIONING FROM SOFTWARE REQUIREMENTS MODELS TO DESIGN MODELS

PI: Jon Whittle – QSS Group, Inc.

Government POC: Michael Lowry – ARC

Period of Performance: 10/02 - 09/05

Many large NASA software projects give software modeling top priority and use state-of-the-art modeling languages, such as UML, to capture requirements and designs. However, current tools offer no support for maintaining the consistency of software models across the software life cycle. This leads to discontinuities that make it difficult to trace the linkages between requirements and implementation and can also lead to design and coding errors. Often, the artifacts or models produced during one phase of the development process get thrown away or remain as mere (and sometimes obsolete) documentation when the transition to the next development phase happens. Methodologies and tools for building models developed by refining patterns for UML sequence diagrams in one phase constructively from those in the previous phase will lead to increased traceability and fewer design and coding errors.

VALIDATION OF SYSTEM SAFETY USING BAYESIAN BELIEF NETWORKS

*PI: Joanne Dugan – University of Virginia
Government POC: Daniel Solomon – IV&V
Period of Performance: 10/01 - 03/05*

Excellent analysis techniques exist for safety assessment, including formal (axiomatic methods), testing, fault injection, inspections, etc. However, no one method is appropriate for the entire system, and all are difficult to apply to novel systems. A methodology is needed for combining and evaluating qualitative and quantitative evidence of safety gathered via different techniques. The objective of the research is to develop a methodology to validate the safety of a safety-critical computer-based system through the “safety case” approach. A “safety case” is built by collecting and evaluating information related to V&V activities, and Bayesian belief networks (BBN) are then used to create an evaluation process that is both qualitative and quantitative.

A COMPOSITIONAL APPROACH TO VALIDATION OF FORMAL MODELS

*PI: Bojan Cukic – West Virginia University
Government POC: Ken McGill – IV&V
Period of Performance: 01/04 - 12/06*

Proving the correctness of the developed specification with respect to the requirements is one of the most important and difficult tasks performed by NASA IV&V personnel. The research is focusing on compositional approach of validation of the formal specifications using visualization, simulation, formal methods and testing. The basis of our approach is the SCR (Software Cost Reduction) Formal Method and its finite state model of the system. An SCR

specification can be executed by the existing SCR simulator and tested—either automatically (i.e., random testing) or manually. In order to facilitate testing of the specification simulation, we are investigating the creation of visual interfaces. The visual interfaces will hide the complexity of the model (and the formal mathematical notations being used) from the users and the domain experts. Performing testing using these visual interfaces would allow the V&V practitioner to focus on the expected behavior of the system and the correctness of the specification.

IMPLEMENTING “MARTHA” A NEXT-GENERATION TESTABLE LANGUAGE

*PI: Tim Menzies – West Virginia University
Government POC: Ken McGill – IV&V
Period of Performance: 01/04 - 12/06*

IV&V struggles to test software. Much research is being conducted to support the testing of the current generation of software. The current generation of software tools is optimized for execution speed (e.g., “C”) or usability (e.g., Python or UML). Here we have taken a bold step away from current practice and ask the fundamental question: What would a software language look like if it was designed for testability? Our premise has been that a testable language is a reflective language that automatically and routinely explores itself looking for previously undetected interactions. The object of the research is to design and implement an interpreter for a next-generation testable language that automatically seeks the “unknown knowns.”

LYAPUNOV STABILITY ANALYSIS AND ONLINE MONITORING

*PI: Bojan Cukic – West Virginia University
Government POC: Ken McGill – IV&V
Period of Performance: 05/03 - 04/06*

Artificial Neural Networks (ANN) play an increasingly important role in flight control and navigation, two focus areas for NASA. They are very useful in application domains that arise routinely within NASA’s practice areas, where autonomy and adaptability are important features. A major obstacle, however, precludes the widespread use of ANNs in navigation and control systems; most of the certification standards that NASA and other federal agencies (such as FAA) impose on such life-critical and mission-critical applications cannot be met with today’s V&V technology. No existing software V&V method/technique can be applied to systems, which contain on-line learning artificial neural networks. The objective of this ongoing project is to produce a framework for reasoning about adaptive systems. Online Adaptive Systems are systems whose function evolves over time, as they improve their performance through online learning. The advantage of adaptive systems is that they can, through judicious learning, react to situations that were never individually identified and analyzed by the designer. Online adaptive systems are attracting increasing attention in application domains where autonomy is an important feature, or where it is virtually impossible to analyze ahead of time all the possible combinations of environmental conditions that may arise. An archetype of the former are long term space missions where communication delays to ground stations are prohibitively long, and we have to depend on the systems’ local capabilities to deal with unforeseen

circumstances. While experimental success suggests significant potential for future use, the critical factor limiting wider use of neural networks and other soft-computing paradigms in process control applications, is our inability to provide a theoretically sound and practical approach to their verification and validation. This research will help develop not only autonomous learning, but learning with a confidence attached to it; we can know how confident the craft is that its behavior is correct. These techniques will help a craft learn not only how to operate safely in normal states, but also how to react in failure modes, how to stabilize itself, and to learn from the failure.

PERFORMABILITY OF WEB-BASED APPLICATIONS MODELS

PI: Katerina Goseva-Popstajanova – West Virginia University
Government POC: Ken McGill – IV&V
Period of Performance: 10/02 - 09/06

Many factors affect dependability (e.g., availability, reliability, safety, and security) and performance of complex computing systems and applications executing on them. Modeling and simulation methods and tools that are used to understand the isolated quality attributes have been reasonably successful when computing systems and the applications were relatively simple. However, these methods do not have the capability to provide system view and analysis, nor can they provide a well-defined hierarchical analysis and structuring needed to model systems of the level of complexity under consideration. The objective of the ongoing research is to develop scalable approaches that allow models, measurements, and simulators with different levels of details and abstraction to be combined together to analyze multiple quality attributes and their tradeoffs for

complex distributed systems. To demonstrate the validity of the developed methods and techniques we will apply them on the web-based applications.

RISK ASSESSMENT OF SOFTWARE ARCHITECTURES

PI: Hany Ammar – West Virginia University
Government POC: Ken McGill – IV&V
Period of Performance: 10/03 - 12/06

The report of the Columbia Accident Investigation Board (issued August 24, 2003), repeatedly mentions the keywords risk/hazard analysis and mitigation in its recommendations. Risk/hazard analysis is clearly an important focus area of research and development at NASA. The problem addressed in this research is risk assessment of software specification and design artifacts based on software product metrics. The research is seeking to develop techniques for severity analysis and a methodology for maintainability-based risk assessment at the architectural level. The work builds on our recent techniques for risk assessment of UML dynamic specifications, and attempts to integrate this work with risk assessment-based tools such as CARA and DPP used in NASA projects. The objective is to extend and integrate the techniques for risk assessment of software artifacts into the Defect Detection and Prevention (DDP) process developed at JPL and the NASA Criticality Analysis and Risk Assessment (CARA) process.

SEE MORE! LEARN MORE! TELL MORE!

PI: Tim Menzies – West Virginia University
Government POC: Ken McGill – IV&V
Period of Performance: 12/03 - 12/06

As the sole entity with the responsibility for IV&V of all NASA mission software, the IV&V Facility is in a unique position to create and maintain a master repository of software metrics. But if the collected metrics aren't used, then the stored numbers become a sarcophagus, not a repository. NASA needs an active group exploring the details of the collected data and reporting their findings. There exists within NASA projects repeated and important patterns about software development that can be found by machine learning queries to a metrics repository. If these patterns can be found, then the process of generating software for NASA can be optimized. If we ignore old experience we run the risks of making the same mistakes twice, of risking human life and mission success over issues that are now avoidable.

TOWARD MORE REALISTIC SOFTWARE RELIABILITY PREDICTIONS

PI: Katerina Goseva-Popstajanova – West Virginia University
Government POC: Ken McGill – IV&V
Period of Performance: 10/03 - 09/06

This initiative has been focused on development of more realistic and accurate estimation and prediction of software reliability based on empirical studies. The research addresses two important phenomena: uncertainty in software reliability due to errors in the operational profile and the effect of failure clustering on software reliability predictions. The work on uncertainty in software reliability

builds on recent contributions on methods for uncertainty analysis. Empirical case studies are being used to verify and validate our methodology for uncertainty analysis and to compare different methods based on real data. The same empirical studies are being used to build more realistic software reliability models that consider the correlation of successive software executions and analyze the effects of failure clustering on software reliability predictions. Accurate prediction of reliability is important because we know we cannot test every piece of code, so we need to test what is most important. In this case, important is what is executed most, or what most frequently affects other pieces of code.

VERIFICATION AND VALIDATION OF ADAPTIVE SYSTEMS

PI: Bojan Cukic – West Virginia University

Government POC: Ken McGill – IV&V

Period of Performance: 10/01 - 12/05

SARP Results:

<http://sarpresults.ivv.nasa.gov/ViewResearch/35.jsp>

Online adaptive systems play an increasingly important role in systems where autonomy is involved. They are very useful in application domains that arise routinely within NASA's practice areas, where plasticity is desired as a principal feature. However, its adaptive learning behavior also poses a major obstacle impeding the widespread use of such systems in terms of software V&V. For adaptive systems, most certification standards that NASA and other federal agencies (FAA) consider appropriate for life-critical and mission-critical applications cannot be met with today's V&V technology. Existing software V&V method/technique cannot be applied to online adaptive systems.

This research is developing a validation framework for such systems. More specifically, this research explores a practical approach to the V&V of online adaptive systems tested mainly within the Intelligent Flight Control System (IFCS), one of the safety-critical systems NASA currently investigates. In the IFCS project, neural network is adopted as the online adaptive learning paradigm. However, the scope is not limited to this specific control application; the proposed framework will be extendable as a generic model for V&V of online adaptive systems in other application domains of interest to NASA.

CONSTRAINT DETERMINATION ON SIMULINK MODELS

PI: Mike Biems – SAIC

Government POC: Steve Pukansk – IV&V

Period of Performance: 10/04 - 10/07

The problem of determining variable constraints is not just a theoretically interesting problem but rather is a significant pragmatic problem within programming, testing, and safety assurance. Variables whose values can exceed safety and reliability limits can result in mission failure. Conversely, variables whose values cannot reach portions of their specified range can prevent software, and the hardware the

software controls, from providing required functionality. This research and development effort focuses on determining variable constraints with MATLAB/Simulink models and the corresponding automatically generated source code produced by these models. The results of this effort will place software tools in the hands of practitioners who will quickly determine the constraints of both internal and external variables of both MATLAB/Simulink models and the source code produced from these models.

DEVELOPMENT OF METHODOLOGIES FOR IV&V NEURAL NETWORKS

PI: Brian Taylor – ISR

Government POC: Markland Benson – IV&V

Period of Performance: 05/02 - 09/05

SARP Results:

<http://sarpresults.ivv.nasa.gov/ViewResearch/11.jsp>

Little research has been found that addresses IV&V of neural nets in adaptive flight controllers that are learning in real time and adapting to live flight conditions. A neural network is technology that has the ability to adapt over time based on data observed. This is unlike traditional software that has a fixed behavior when written. The dynamic nature of neural networks allows developers to solve

Autonomy and Neural Nets

The study of artificial intelligence and neural nets deals largely with the effort to imbue machines with human qualities such as autonomy, the ability to learn from experience, and even intuition and creativity. To explore space we need the help of smart crafts which can act on their own to some degree. This need for autonomy is driven by the distance and difficulty involved in the missions we plan. When we consider the affect of lag on the crafts we send out into the Universe, the need for agents that can learn is obvious. Many of us have had the experience of driving in an unfamiliar city with the aid of GPS. Now consider that same experience if you could only receive one instruction every 25 minutes; the problems of lag and autonomy are clearly linked.

problems that were difficult or impossible with traditional software. However, assuring that a neural network will not perform an unsafe behavior cannot be done with current software verification processes. Such assurance is particularly important in NASA missions where errors can lead to loss of life or loss of critical assets. The initiative has a goal of creating a set of processes and advice that will allow IV&V practitioners to be able to assure quality of neural networks used in NASA applications. The products of the initiative are techniques for selecting the right type of neural network for a given task, techniques to test neural networks and extract neural network knowledge for evaluation, and methods for assessing the risks posed by the neural network on its environment.

IMPROVING REQUIREMENTS TRACING AND IV&V VIA INFORMATION RETRIEVAL AND TEXT MINING

PI: Jane Hayes – University of Kentucky
Government POC: Stephanie Ferguson – IV&V
Period of Performance: 10/04 - 01/05

SARP Results:
<http://sarpreresults.ivv.nasa.gov/ViewResearch/25.jsp>

IV&V tracing of requirements to design, code, and/or test cases is difficult. It must be done quickly and accurately, and often must shortly be redone on updated documents/artifacts. IV&V tools are needed to automate linking between levels of documents/artifacts vs. developer's tools that only record links during decomposition. This research is developing improved methods for finding candidate links between document/artifact levels using appropriate algorithms and techniques from the field of Informa-

tion Retrieval. Further, it will develop a toolkit of tracing algorithms and integrate it with at least one IV&V tool currently in use.

INTERFACE VALIDATION FOR DISTRIBUTED SOFTWARE SYSTEMS

PI: Pavan Rajagopal – Titan Corporation
Government POC: Deborah Kromis – IV&V
Period of Performance: 10/04 - 10/07

Past history indicates that many failures in distributed software systems are attributable to errors and deficiencies in interactions between software components. Comprehensive validation of command and data exchange between the components of a distributed software system is crucial to validation of the entire system but typically is not performed. Two major reasons for this omission are either that the activity required to accomplish this validation has not been defined, or the effort required is perceived as being unfeasible in terms of time and cost. Instead, validation of interfaces between software components is typically performed through system integration testing. This type of testing, however, is designed to concurrently exercise groups of Computer Software Component Interface (CSCIs) and lacks the detail required to comprehensively validate command and data exchange across the interfaces. System integration testing also occurs late in the development cycle and deficiencies found at this stage are expensive to fix. The research and development in this study will attempt to address this deficiency by defining an IV&V process for performing software interface validation and developing tools to make it feasible.



An illustration is shown of one of NASA's experimental planes, an F15B. Part of the control Technology is the carards (small wings) just ahead of the wings. The F15B also has multi-directional thrust vectoring nozzles on its Pratt & Whitney jet engines. Improving maneuverability. These are linked to an advanced flight control system. Several of the research initiatives working with Intelligent Flight Control Systems (IFCS) Programs test their research on models of the F15.

INTEGRATING MODEL CHECKING AND PROCEDURAL LANGUAGE

PI: David Owen – ProLogic, Inc.
Government POC: Ken McGill – IV&V
Period of Performance: 09/03 - 07/04

This initiative developed a fast, memory-efficient, fault-detection tool which is used for automatic verification of software models. While automatic verification tools often have a problem scaling up to large systems, LURCH was developed to use little memory and run quickly even when exploring very large search spaces. This allows LURCH to

provide an overview of an entire system, making it ideal to use as a first pass technique. This tool shows sufficient promise that it is currently being used, in conjunction with other techniques, by researchers at JPL and WVU.

IV&V CODE LEVEL METRICS DATA PROGRAM

PI: Mike Chapman – Galaxy Global Corporation

Government POC: Pat Callis – IV&V

Period of Performance: 08/03 - 02/05

For serious research to thrive, it is necessary for researchers to have access to sufficient relevant data. For researchers whose work will impact NASA projects and practices, data from NASA development projects and missions is crucial; however, for a variety of reasons, NASA data is often difficult to get. The Code Level Metrics Data Program exists to help give other researchers access to relevant data that would otherwise be inaccessible. One of the most important aspects of this effort, as far as supporting other research is concerned, is that information from important NASA projects is sanitized, thus making it available to inform research. This effort will also support and enhance the generation of software metrics including recommendations of the types of metrics to generate for a given project. To the extent possible, this effort will assist researchers in generating additional data for an original data set in order to broaden or deepen their data set for that project. Software metrics currently being generated include, but are not limited to, complexity, Halstead, object-oriented metrics, and error density metrics.

MITIGATING THE RISK OF LEGACY SOFTWARE ON NASA SPACECRAFT

PI: Lydia Candland – TMC

Government POC: Gerald Gilley – IV&V

Period of Performance: 09/04 - 08/05

The purpose of this study is to identify and determine the impact of using legacy software on NASA spacecraft, and to develop tools that mitigate the risks of using legacy spacecraft software. Routinely, the reuse of spacecraft software is a part of NASA's IV&V program scenario. However, the legacy software is not currently verified or validated for its new environment, even though the legacy artifacts may be available to the IV&V team. Further, while the various IV&V teams often see the need to evaluate the reused code, they have no data to make an argument for re-verifying that code.

NASA IV&V COMMON DATA REPOSITORY PILOT PROJECT

PI: Paul Garnett – MSIS

Government POC: Aaron Wilson – IV&V

Period of Performance: 09/04 - 09/05

The objective of this project is to achieve optimal site-wide efficiencies and savings by developing a data dictionary that can then be used to fully define and populate a Common Data Repository (CDR). The CDR should be designed to incorporate existing databases to the extent practical by utilizing data warehousing and data mart concepts.

PROGRAMMABLE LOGIC DEVICE IV&V RESEARCH

PI: Mike Biems – SAIC

Government POC: Richard Grigg – IV&V

Period of Performance: 07/04 - 06/06

The use of Programmable Logic (PL) is becoming commonplace within NASA projects, facilities and research. As part of this trend, Programmable Logic is seen more frequently in space systems' software undergoing Independent Validation and Verification (IV&V) at NASA's IV&V Facility. Programmable logic chips, such as Field Programmable Gate Arrays (FPGAs) are being employed to standardize functionality formerly performed by the Central Processing Unit (e.g., battery charging algorithms) and to create custom capabilities (e.g., science domain specific massively parallel data compression) within satellites and instrumentation. PL software is tested for functionality, boundary conditions, and operational simulation, but most of this logic programming software is not subjected to verification and validation methods employed in main stream software. This research will focus specifically on FPGAs within the PL family and aims to identify design fault characteristics specific to the FPGA and then explore the feasibility of applying existing inspection methods that may be candidates for direct application to FPGA designs. Once a suitable set of methods has been identified, the research will result in the development of modifications to the design phase, peer, and design review methodologies. Incorporating and prototyping those methods will be done by providing Independent Verification and Validation in a NASA case study.

RETURN ON INVESTMENT FOR IV&V

PI: James Dabney –Titan Corporation

Government POC: Wes Deadrack – IV&V

Period of Performance: 09/02 - 01/05

SARP Results:


<http://sarprelts.ivv.nasa.gov/ViewResearch/24.jsp>

Independent Verification and Validation (IV&V) has many benefits, but it is difficult to quantify those benefits. Consequently, a common argument against IV&V is that the expenses exceed the value added. The ongoing effort of this research is to produce a Return on Investment (ROI) model that could be tailored to an individual project. Thus, the effects of different development reliability requirements, different personnel talent, different tool sets, etc., could be considered. Up to this point, only anecdotal statements are available to demonstrate the benefit of IV&V. This research outlines a set of activities to produce a tailorable ROI model suitable for NASA mission-critical software projects, and based on historical data and the baseline NASA IV&V process. It is important to start with a clear definition of ROI. In the case of software IV&V, ROI has multiple components. The primary benefit of IV&V is the reduction in the number of high severity software errors in the deployed software. Here, we define high severity errors as those errors that, when manifested during operations, could plausibly result in the loss of life, loss of high value asset, or mission failure. Attempts to ascribe dollar values to such errors are controversial due to the many elements of cost that could be involved (value of human life, national prestige, agency embarrassment, etc.). Even for cases in which the component has an identified dollar value (e.g., loss of high value asset), it is difficult to

achieve consensus on whether detection of a defect or even a set of defects really approaches that value. A second ROI approach is to consider only cost-to-fix (referred to as Simple ROI in this proposal). In this approach, the cost of an error is limited to the cost to correct it. Since IV&V results in earlier detection of many errors, a direct and less controversial cost savings can be computed. ROI can then be defined as the ratio of cost savings to the cost of IV&V. However, that approach lacks the large intangibles that come from detection of high-severity defects. This proposal defines an approach that molds the above two sources of ROI into a single, nationally-recognized model, calibrated with extant IV&V data, to give ROI estimates tailored to a specific project.

Shown below is the Omega Nebula sent back from Hubble.





NASA IV&V provides assurance for our customers' safety and mission critical software in the areas of safety, reliability and availability; performs leading-edge research that improves IV&V and software assurance methods, practices and tools; **participates in the vitality of the community, as well as engages the public in the experience and benefits of exploration and discovery.**



PILLAR III: OUTREACH

Goal: Be an active partner in our communities' futures through educational and community outreach activities and proactive service.

Since our doors opened in 1994, the IV&V Facility has had an impact on the community as an employer, educator and neighbor. As an employer, IV&V has sought to inspire West Virginians to join the NASA family. Donna Ozburn, who now manages the Outreach Program, was the first West Virginian hired as a civil servant in 1994. Roger Harris, hired as a civil servant in 2004 through the IV&V Co-op Program, is the most recent West Virginian to join the NASA family. Forty-four percent of our civil service personnel are native West Virginians.

As an educator, the IV&V Facility strives to inspire the next generation and motivate students to pursue careers in science, technology, engineering, and mathematics (STEM) and to engage the public in the experience and benefits of exploration and discovery. NASA IV&V reaches for the stars from West Virginia, from its unique Kindernauts program for five-year-olds to its classes for more senior students in the Lifelong Learners Program at Fairmont State University (FSU). Star Labs and GPS Labs for K-12 educators developed by the Educator Resource Center (ERC), along with the Student Outreach Program's high school apprenticeship opportunities such as SEAP and SHARP, college Interns and Co-ops, round out a portfolio of programs designed for students of every age.

As a neighbor, the "NASA Family" at the IV&V Facility has established a place in the community and has shared its concerns and celebrations with generosity and enthusiasm for a decade. With each passing year, individually and organizationally, IV&V and its employees have become more invested in the community. This year, the impact of that investment can be seen locally, throughout the region and across the State.



Shown above is Nelson Keeler, Valerie Graves, Karen Davis, Ed Weiler, and Donna Ozburn.

The Educational Outreach Team at the NASA IV&V Facility was honored with the Excellence in Outreach Award on October 6, 2004. The award was presented by Center Director Ed Weiler on behalf of the Goddard Space Flight Center in Greenbelt, MD, in recognition of outstanding achievements in educational outreach. Specifically, the team's efforts in continually demonstrating its excellent performance in providing outreach opportunities and services to West Virginia educators, businesses, the community, and the general public was recognized. The Educational Outreach Team members are Donna Ozburn (NASA Education Outreach Project Manager), Valerie Graves (Fairmont State University Student Outreach Program Manager), Karen Davis (West Virginia University Educator Resource Center Program Manager), and Cynthia Keeling (West Virginia University Educator Resource Center Education Specialist).

EDUCATION RESOURCE CENTER

The NASA IV&V Facility Educator Resource Center (ERC) was established in 1997 by a steering committee consisting of NASA personnel, educators, and community members. It continues to serve West Virginia educators and leaders through a grant to West Virginia University from the NASA IV&V Facility.

The ERC provides expertise and facilities to help educators access and utilize science, mathematics, geography, and technology instructional products aligned with national standards and appropriate state frameworks that are based on NASA's unique mission results. The ERC works to demonstrate and facilitate the use of educational technologies; provide in-service and pre-service training utilizing NASA curriculum support products; and partner with local, state and regional educational organizations to become part of the systemic initiatives in the State. Since its inception, the ERC has had an important impact on the community it serves.

In 2004, the ERC provided 57 workshops to pre-service and in-service educators. The ERC focused its efforts on providing a greater emphasis on networking and training designed to ensure success in the classroom. The ERC team participated in local, regional and national conferences and events such as the West Virginia Council for Teachers of Mathematics (WVCTM); an event for the West Virginia Gifted and Talented Program; the International Space Station Educators Conference – ISSEC; and the National Science Teachers Association (NSTA) Conference.

The ERC excels in networking to strengthen partnerships and programs. In 2004, the ERC served on the Appalachia Educational Laboratory (AEL) State Advisory Team; served on the MERIT

(Mathematics Education Research Initiatives for Teachers, a state math grant) Advisory Council; and served on the Exhibitor/Vendor Committee for the MSTC–WV Science Teacher Association (WVSTA) Conference. The ERC hosted the State Math and Science Coalition meeting; partnered with the Marion County Reading Council; participated in the Central Appalachian Astronomy Club's Astronomy Day; and hosted the Mount View Middle School in McDowell County, chosen as West Virginia's first NASA Explorer School.

The ERC is proud of its efforts to support the grant proposals of its partners. A number of grants were awarded in 2004 that provided many West Virginia educators with professional development opportunities. The No Child Left Behind grant from the Higher Education Policy Commission awarded MSTC-GLOBE and five partnering counties \$48,000 for summer training and fall follow-up sessions. All sessions were highly successful with wait lists at each site. The 21st Century Community Learning Center grant was awarded to our partner, RESA VII (Regional Education Service Agency), and to our partner, Marion County, providing HOSO (Hands On Science Outreach) training for after-school science programs for five years. The five-year Fairmont State University grant GEAR-UP provides incentive for middle school students to pursue college career paths. GEAR-UP also provided schools with funds for Day in the Park and teacher workshops. The ERC also supported the Marion County Teacher Academy and Project Enrich to make possible summer workshops.

To better serve its clients and partners, ERC staff members participate in professional development and training programs designed to enhance their skills and increase their knowledge of NASA's educational tools and programs. This year, ERC staff attended the Office of Space Science (OSS) and Earth Science Enterprise (ESE) training; the National Space Biomedical Research Institute (NSBRI); the Math Education Research Initiative for Teachers (MERIT) Considering New Curricula sessions; the Solar System Educator Program (SSEP); national and regional ERC Network conference trainings; and the Appalachian Education Laboratory (AEL) State Team meeting. The ERC also partnered with the Space Grant Consortium to provide support to the Synergy Project, including GPS training.

For further information about the NASA IV&V Educator Resource Center, visit <http://erc.ivv.nasa.gov>.



Kindernaut Caleb Ozburn, Mason Dixon Elementary School, models the space suit used in the NASA IV&V Educator Resource Center's Kindernaut Program.

DAY IN THE PARK

“Day in the Park” is a unique and exciting annual event at the NASA IV&V Facility. In collaboration with the West Virginia High Technology Consortium Foundation, “Day in the Park 2004” was conducted on September 21, on the grounds of both facilities in the Technology Park. Led by NASA IV&V professional staff, enthusiastic volunteers from both organizations conducted a multi-faceted event designed to encourage students to pursue careers in science, technology, engineering and mathematics (STEM) by bringing them together with scientists, practitioners and astronauts for a day of fun and inspiration.

Approximately 850 seventh-graders from West Virginia (Monongalia, Marion, Harrison, Lewis, Doddridge, and McDowell counties) participated in hands-on activities and visited with representatives of a variety of technical fields. Students from Mount View Middle School, West Virginia’s NASA Explorer School, traveled a total of eight hours to participate in “Day in the Park 2004.” Teachers from this rural school appreciated NASA IV&V’s special invitation to participate, and felt that the event would give their students hope that they can “go places in life.”

Former NASA astronaut, Frank L. Culbertson Jr. (Captain, USN, Ret.) opened the day with an inspiring presentation about his career as an astronaut, and took time to join the students later in the day during lunch to chat with them informally. Mr. Culbertson flew on STS-38 Atlantis (1990), STS-51 Discovery (1993), and STS-105 Discovery (2001) that docked with the International Space Station, where he lived and work for 129 days. Captain Culbertson was the only American not on Earth on September 11, 2001. At the time, he was an Expedition 3 crew member on board the International Space Station and was witness to the



Photo: Ron Rittenhouse of the Dominion Post

Former NASA Astronaut Frank L. Culbertson, Jr., describes his experiences as Shuttle Commander and Crew Member.

damage done to the World Trade Center towers in New York City, Shanksville, Pennsylvania, and the Pentagon in Washington, D.C., 230 miles below. Captain Culbertson concluded his presentation with a challenge to the students to dream big dreams, and keep in mind that someone in their age-group will be the first person to go to Mars.

Also featured at “Day in the Park 2004” was Coalwood, West Virginia, native Roy Lee Cooke, a founding member of the Big Creek Missile Agency and one of author Homer Hickam’s original “Rocket Boys”. Many of the students were familiar with Hickam’s book or with the movie, *October Sky* that featured the story of the rocket boys, and engaged Mr. Cooke in a lively question and answer session. He shared his experiences growing up in West

Virginia, and encouraged the students to stay in school and reach for their dreams.

Louis Carfagno, a space suit engineer and former pilot, demonstrated how a space suit was designed and fitted for astronaut training and space flight. Mr. Carfagno, who describes himself as a celestial tailor, passed parts of the space suit among the students and answered their questions about the details of ensuring the safety of astronauts traveling in the hostile environment of space. He encouraged students to set high goals for themselves and work diligently to achieve them by taking advantage of their educational opportunities.

Students enjoyed lunch together and explored science and technology with hands-on activities at the West Liberty State College SMART-Center exhibits, while local businesses provided aeronautics, model rocketry, and satellite research to complete this spectacular day.



Rocket Boy Roy Lee Cooke shares stories about his childhood in West Virginia and encourages students to reach for their dreams.

Louis Carfagno, a Space Suit Engineer and former pilot, shares knowledge about the features of an astronaut's space suit.



Photo: Ron Rittenhouse of the Dominion Post

Photo: Ron Rittenhouse of the Dominion Post

STUDENT OUTREACH

In April of 2004, as a reflection of IV&V's commitment to the community and desire to further "engage the public in the experience and benefits of exploration and discovery," NASA IV&V established the Student Outreach Program. With increasing demands on the Educator Resource Center, and more frequent requests for student support, it was deemed necessary to expand the NASA IV&V Outreach activities. To meet the community's educational needs and respond to its growing interest, a Student Outreach Grant was awarded to Fairmont State University (FSU). Students at all levels are served by this grant. The goals of the Student Outreach Program are to inspire and motivate students of every age to pursue careers and their interests in science, technology, engineering and mathematics, and to engage the public in shaping and sharing the experience of exploration and discovery.

Photo: Ron Rittenhouse of the Dominion Post



Day in the Park students make their way toward the NASA IV&V Facility.

Presentations, career fairs, science fair judging, and special activities are some of the additional ways that the NASA IV&V Student Outreach Program works to increase scientific literacy. This year, Career Fairs were conducted at the "Journey to the Future" Middle School Career Fair; the Marion County 4-H Club Fair; the Preston County High School GEAR-UP Career Fair; and the East Fairmont High School Career Awareness Fair.

The NASA IV&V Student Outreach Program provided speakers to the Young Marines of Cumberland Sands, a special program for at-risk youth; and to the Martinsburg STARBASE Kids' Camp, a WV National Guard Program focused on keeping kids free from substance abuse.

The NASA IV&V Student Outreach Program visits classrooms of students in grades pre-K through 16. The visits are tailored to the needs of the educator, and often focus on a central theme. Hands-on activities and experiments are conducted to explore science, engineering, and math concepts at every grade level. In 2004 Student Outreach spent time at Long Drain Elementary School, where the effects of long-duration space travel on humans were studied, and at Cheat Lake Middle School for a simulation of a mission to Mars. Local teachers have taken advantage of IV&V's services to make science and math exciting and motivating their students to pursue their interests and build their skills for technical careers.

The Student Outreach Program hosted a visit to the NASA IV&V Facility for the Big Brothers and Big Sisters of North Central West Virginia. The organization toured the Facility and met with civil servants and contractors to promote awareness of their program and its activities in the community.



Shown outside the NASA IV&V Facility are the Fairmont State University Lifelong Learners with Valerie Graves, Student Outreach Program Manager.

The Student Outreach Program designed a 5-week course entitled “NASA IV&V Facility—Projects, People, Presence,” for Fairmont State’s Lifelong Learners, a class of individuals 55 years of age and older, are interested in continuing to learn through educational and recreational programs. Ned Keeler, the Facility’s Director, welcomed the group and engaged them in a discussion of topics relating to NASA and its mission. At each weekly meeting, a new topic was presented. Donna Ozburn and Valerie Graves presented information about the Facility and its Outreach Program. Marcus Fisher, ISS Project Manager, offered a presentation on the International Space Station. John Marinaro, IV&V Services Lead, spoke about NASA and aeronautics, and Ken Costello, IV&V’s Chief Engineer, concentrated on Mars. The final session included instruction and testing offered by Phil Merritt, IV&V Computer Engineer, of the Space Shuttle Landing and International Space Station Docking Simulator.

The NASA IV&V Facility is home to a Shuttle Landing and International Space Station Docking Simulator. Group visitors to this realistic simulation included the Young Marines of Cumberland Sands; special needs students from Dunbar Middle School and their parents; the Association of Computer Machinery (ACM) students from Davis and Elkins colleges; and Fairmont State’s Lifelong Learners (LLL).

“Wish I were ‘young’ as this all makes me feel—would like to live to see the next 20 years.”

- Lifelong Learner

The NASA IV&V Facility donated copies of Homer Hickam’s *Rocket Boys* to students who participated in a bottle rocket launch contest as part of the Frieda J. Riley Teacher Award ceremonies. The award honors an American teacher who works with a physical disability, teaches in an especially challenging educational environment, or one who has performed a heroic act by making an exceptional, personal or physical sacrifice on behalf of students. A poster contest for high school students, an essay contest for senior citizens, and an appearance by the four “Rocket Boys” (Roy Lee Cooke, Jimmie O’Dell Carroll, Willie “Billy” Rose, and Quentin Wilson) helped to make this a memorable event.

“Inspiring the Next Generation Day” was held at the NASA IV&V Facility as part of national “Bring Your Child to Work Day.” The Student Outreach Program designed hands-on activities using NASA curriculum to create a day of educational adventure for Facility employees’ children as they learned more about NASA projects.

For further information about the Student Outreach Program contact Valerie.Graves@ivv.nasa.gov.

“The final effect of your involvement may be years in coming, but it is an invaluable factor in motivating and encouraging our students.”

—From a teacher after a career fair at F.S.U.

COOPERATIVE EDUCATION PROGRAM

NASA IV&V's Cooperative Education Program is an important link in the educational process that integrates college-level academic study with meaningful work experience. This allows the students, through study and work experience, to enhance their academic knowledge, personal development, and professional preparation. Additionally, Co-op employees earn income that is based on the level of education and work experience they have attained.

The NASA IV&V Facility benefits from the Co-op Program in many ways. The program attracts students preparing for careers in a shortage category (engineering and science); permits selection for career jobs on the basis of proven performance; supports equal opportunity; and generally helps to more directly relate the efforts of educators to occupational needs of employers and students. Applicants must have completed 30 semester hours; be a student at an accredited university; be enrolled in their school's Cooperative Education Program; be a U.S. citizen; and have a good scholastic standing (2.9 G.P.A. overall).



Phillip Merritt, West Virginia University. Phil's projects were developing a Shuttle Simulator and performing test script analysis. He received his masters in Software Engineering from WVU in December, 2004.

Aaron Wilson, West Virginia University. Aaron's projects were developing a Shuttle Simulator and performing test script analysis. He was converted to a full-time permanent civil servant in August 2004, after graduating from West Virginia University with a masters in Software Engineering.

*For further information about the Co-op Program contact
Donna.S.Ozburn@nasa.gov.*

INTERNSHIP PROGRAM

The IV&V Facility strives to bring new talent to the Agency through internships. These internships cover many ranges of academic skill and encompass the common practices within the government that instill a high degree of competency to further prepare students for success in their careers.

The purpose of the NASA IV&V Facility's internship program is to provide added support to projects and research being conducted at the Facility, while providing paid work experience for undergraduate students and create learning opportunities along with the additional potential for being selected as a NASA Co-op.

Shown above are three of the 2004 interns, Danielle DeAngelo, Dale Everett, and Brendan Gibit (shown left to right).



NASA IV&V 2004 Interns

Brendan Gibit, West Virginia University. Brendan's project was to assist the New Business Office with mission model tracking improvements and monitoring of Monthly Status Reports (MSRs).

Matt Menas, Fairmont State University. Matt's project was to assist with the technical library functions and create websites for the ERC and technical library.

Dan Nawrocki, West Virginia University. Dan's project was to expand the capability of the Shuttle Simulator and develop the Facility's Simulation Lab.

Ryan Schmidt, West Virginia University. Ryan's project was to develop tested/simulation for analysis and test of flight software using 8051 microcontrollers.

Roger Harris, Fairmont State University. Roger's project was to perform development and maintenance of the Tools Lab website and the Resource Management Office website. Roger was accepted into the Co-op Program in December 2004.

David Buckingham, West Virginia University. David's project was to develop a requirements repository for the International Space Station IV&V.

Dale Everett, West Virginia University. Dale's project was to provide research program planning support, research initiative support, and research website development.

Danielle DeAngelo, Fairmont State University. Danielle's project was to provide technical assistance to the IV&V Services Lead and various project managers for the development, maintenance and enhancement of management information spreadsheets, databases, and documents.

*For further information about the Intern Program contact
Donna.S.Ozburn@nasa.gov.*

APPRENTICESHIP PROGRAM

The NASA IV&V Facility offers a select group of students the opportunity to participate in intensive science and engineering apprenticeship programs. The Summer High School Apprenticeship Research Program (SHARP) and the Science and Engineering Apprentice Program (SEAP) are conducted for eight weeks each summer.

After participating in an orientation process, selected students are assigned to work with a NASA IV&V or West Virginia University mentor in a specific technical area. During the apprenticeship, the students carry out assignments, prepare written reports, make

oral presentations, and participate in a variety of enrichment activities, such as career counseling and tours.

The programs are available to students aged 16 and older in all high schools within a 50-mile radius of the NASA IV&V Facility. The schools represented in 2004 were East Fairmont High School (Marion County); North Marion High School (Marion County); Bridgeport High School (Harrison County); University High School (Monongalia County); Lewis County High School (Lewis County); Morgantown High School (Monongalia County); and Clay-Battelle High School (Monongalia County).



The purpose of the SHARP and SEAP programs is to teach students the skills needed to pursue careers in science, mathematics, engineering, technology, and geography. From installation and configuration of operating systems and applications, to developing programs to be utilized on current NASA projects, the students build a foundation from which to make educational and career decisions. In addition to technical achievements, students gain skills in presentation, written communication, Website construction, and workplace professionalism. Upon completion of the programs, students have acquired superior skills that will benefit them academically and professionally as they pursue future goals.

Shown at left are the 2004 SEAP and SHARP students.

2004 SEAP and SHARP Apprentices

Codey Smith: Using Metrics to Predict Loss of Function in NASA Software

Matt Wilson: Project Unique Identifier (PUI) Confirmation

Lauren Wiles: Role of Hydrogen in Pd/MgO

Derik VanPelt: Shuttle Simulator Lander Gear

Chase Kempenski: Organizational Graphic User Interface

Ricky Forquer: Testing XML-Based Interfaces for the International Space Station
Portable Computer Systems Release 8 Software

Mike Morehead: EMars – A Three Dimensional Look at Mars

Jennifer Zhang: Molecular-Dynamics Simulations of Silicon/Silicon Nitride Interfaces

B. Ashby Hardesty: Development of SEAP/SHARP Media

Zachary Kirk: Assisting NASA IV&V Code Analysis

C. Ray Parrish: Artifact Evaluation List Manager

Leah Baker: Developing a Search Engine for the NASA IV&V Website

Lauren McCaugherty: Universal Lander Simulator

Jeremy Holt: The MENA Project

**“This has been
a valuable
experience.
Thanks for the
opportunity
and guidance
you have
provided.”**

**–From a former
SEAP student**

NASA FAMILY

The IV&V Facility is home to a diverse team bound together in the most challenging and rewarding of endeavors by mutual respect, commitment to NASA's mission, and a desire to embrace the community in which they reside. The year 2004 was one of unprecedented accomplishment and generosity. The Facility and staff members sought out many opportunities to embody the spirit of service.

The Combined Federal Campaign is a government-sponsored charitable-giving mechanism, much like the public United Way. The NASA IV&V Facility staff of 43 civil servants contributed a record \$18,447 to the local CFC campaign during the Fall 2004 campaign, an average of \$429 per civil servant. This is an example of how our staff members are vitally interested in the health and well-being of the communities in which we live.

Robert J. Netz, affectionately known as R.J., has provided security services to IV&V since the building was under construction. In 2004, R.J. and his family organized a benefit, embraced by the IV&V staff, for the American Cancer Society in memory of his grandmother, E. Lewana Cone. The benefit celebrated the life of Mrs. Cone with live music and fun for everyone attending. A total of \$1,485 was raised and there are plans to make this a yearly event.

The IV&V Facility supports the Scott's Run Settlement House School Supply Give-Away program. Over 430 backpacks and other supplies were given to the children in our community. This was made possible by the personal donations of IV&V Facility employees and was led by Marcus Fisher. In December 2004, IV&V Facility contractors and civil servants raised money to sponsor two families in the Scott's Run Settlement House's



In 1997, Bill Jackson returned to his Appalachian roots to help the NASA IV&V Facility become a NASA center of excellence working as IV&V Project Manager of the Space Shuttle, X-33, X-34, and X-37 projects. Bill is now the IV&V Facility Deputy Director. Born and raised in Beckley, WV, Bill began his NASA career as a Co-op student at the Johnson Space Center while earning his B.S. in Aerospace Engineering. For more than 25 years, he worked at the JSC on various software and systems development projects for Apollo, Space Shuttle, and the International Space Station.

Christmas Adopt-a-Family Program. Christmas gifts were supplied for both families including winter coats, clothing, blankets, toys, books, grocery gift cards, and donated computer systems.

The IV&V Facility also supported the Salvation Army Food Pantries of Harrison, Marion, Monongalia, and Taylor counties, providing non-perishable items collected in a Facility food drive



Since 1994, as individuals and as an organization, NASA IV&V staff members have sought opportunities to contribute their time, resources and talents to the surrounding community.

and money raised from an auction held during the IV&V Facility Holiday Luncheon. Auction items included everything from a pot of chili to a one-hour plane ride for two with the IV&V Services Lead, John Marinaro. A lunch for four at the home of the IV&V Facility Director, Ned Keeler, brought a hefty price. The auction raised nearly \$3,700 for donations to the food pantries of the four counties.

The creative spirit of the NASA Family can be seen in local community theatres as well as in the workplace. Three NASA civil servants are members of local theatre companies M.T. Pockets Theatre and the Monongalia Arts Center. IV&V Facility employees and their families were quick to show their support by enthusiastically attending the productions and participating in fundraising events such as the M.T. Pockets Dinner Theatre and Annual Golf Tournament.



Services Lead-Captain John Marinaro is a Battalion Logistics Officer with the 772nd Troop Command (Aviation) of Williamstown, West Virginia. He is pictured (on the left) with Jeff Bouma during his recent deployment in Hohenfels, Germany (September 2004) to fly helicopters as an observer, assisting in the validation of a US Army Task Force headed for Afghanistan.



FOUNDATION

Goal: Sustain continuous quality improvement, compliance, and innovation throughout NASA IV&V.

Goal: Establish an organizational culture that engages and rewards employees and that cultivates their loyalty and commitment to the NASA IV&V organization.

Goal: Ensure a safe, comfortable, and well-equipped workplace that is conducive to high performance and supports individual and team productivity.

The pillars of the NASA IV&V mission stand solidly on a foundation consisting of a well-defined management system and a state-of-the-art physical plant infrastructure. In 2004, the IV&V leadership and staff fully engaged in a process of management systems and facility management review and reinvigoration. Over the past ten years, NASA IV&V's expanding role throughout the Agency often challenged its workforce and infrastructure to keep pace with its workload. An innovative staff requires effective and efficient systems and processes to succeed. A growing staff requires appropriate technical and physical resources to excel. Support of the many One NASA Agency initiatives is also leading to infrastructure enhancements.

*IV&V, committed to ensuring its reputation
as a center of excellence, focused its attention
on continually improving the managerial
infrastructure that supports its mission.*

INTEGRITY

TEAMWORK

RESPECT

EXCELLENCE

BALANCE

INNOVATION

SAFETY

IV&V MANAGEMENT SYSTEM

“To provide superior quality products and services, through continuous improvement, that meet or exceed customer requirements” was and continues to be the policy statement underlying our requirement to maintain our ISO 9001 certification of the IV&V Management System. In 2004, we improved the IV&V Management System (IMS) by broadening the scope of our certification, strengthening our established processes, and continually improving our systems. The IV&V Facility management and employees are committed to ensuring that the IMS is effective in achieving quality, practicing continuous improvement and satisfying customers both now and in the future.

FINANCIAL MANAGEMENT

Fiscal management is key to any foundation of excellence. During fiscal year 2004 NASA IV&V received \$30.3 million dollars in funding from NASA and Congressional budgets for carrying out its work across NASA. In addition, the NASA Software Assurance Research Program (SARP), which is managed by the IV&V Facility, received funding allocation of \$5.5 million dollars during fiscal budget year 2004. Of the \$5.45 million, the Facility executed \$2.3 million in research activities during the year. The Facility also received funding totaling \$1.1 million directly from project work. Further, the Facility generated approximately \$0.8 million in revenues for the fiscal year through lease arrangements that significantly offset cost of operations. IV&V has enhanced financial management processes that tie into the Agency's Integrated Financial Management Program (IFMP). In 2004 an emphasis was placed upon using a scaled-down version of Earned Value Management (EVM-light), providing more effective management decision making to minimize adverse impacts to projects.

TRAINING

NASA IV&V staff members are encouraged to take advantage of every opportunity to further prepare themselves to meet the challenges of our mission. In 2004, staff members participated in a wide variety of training courses both on and off site, focusing on highly technical subjects, as well as financial topics, human resource management and leadership skills. Facility-wide training was offered to enhance knowledge of contract management and space systems. The entire Facility also participated in colloquia designed to further develop change management and communications skills. Four employees were singularly honored by selection to participate in masters and doctoral programs under the Part-Time Graduate Study Program. These formal training and educational experiences serve to enhance an environment in which staff members naturally and generously share information, knowledge and skills.

EMPLOYEE RECOGNITION

A values-driven Peer Recognition Process was initiated in 2004 at the IV&V Facility. The goal of the process is to identify and reward individuals and groups whose activities best reflect the core values of the Facility. This is a unique opportunity to formally recognize singular or exceptional activities and contributions that, beyond specific job description, serve to further the Facility's technical and institutional objectives and strategies. Fifteen civil servants and contractors, individually or as members of teams, earned the respect and recognition of their peers for their outstanding efforts to bring NASA IV&V values to life within and on behalf of the organization. Also, many IV&V personnel were recognized via established Agency programs.

As the flagship organization within the I-79 Technology Park located in Fairmont, West Virginia, IV&V takes great pride in the physical plant and IT management of its infrastructure. The Facility, constructed in 1993, belongs to the West Virginia University Research Corporation (WVURC), and is operated and maintained by WVURC under contract to NASA. The Facility's first level consists of high quality raised floor computer space protected by an Uninterruptible Power Supply (UPS) system supported by batteries and diesel generators. The IT infrastructure consistently remains a high quality secure capability supporting the Facility's goals.

NASA IV&V believes that the flow of superior business practice revolves around continuous improvement of infrastructure.

PHYSICAL AND IT INFRASTRUCTURE ENHANCEMENTS

Innovation in operations and maintenance has further enhanced IV&V's capabilities in 2004. Of note, the addition of a consolidated tools lab housing IV&V analysis tools and the purchase of additional tools has enhanced the effectiveness and efficiency of IV&V analysis. The replacement of the Facility's telephone system with a Voice Over Internet Protocol (VOIP) system has enhanced capabilities and reduced recurring costs. The Facility led the collaboration of partners located in North Central West Virginia which resulted in the development of the High Speed Optical Network (HSON) group and the installation of a high speed fiber optical network to the area; this resulted in a cost-effective communications capability to the Facility and local area. Because of these capabilities at the Facility, NOAA has leased additional raised floor



Shown above is the sign from the NASA IV&V Facility

space from NASA in 2004 to house one of their super computers. Network operations had been functioning at 99.995% or better up-time for several years and continued this impressive record in 2004. Many activities have taken place in 2004 to accommodate or prepare for the One NASA Agency initiatives that will be implemented in the future to make NASA more efficient and effective.

For further information about the IV&V Management System documentation, visit <http://ims.ivv.nasa.gov/>.



OUR FUTURE

Goal: Advance the NASA IV&V Facility's vision and mission by managing the use of existing resources, collaborating with others, planning future growth.

It is an exhilarating time to work for NASA. The Agency stands at the gateway to amazing destinations. NASA has embraced the Vision for Space Exploration and is charting a bold new course into the cosmos, a journey that will take humans back to the Moon, and eventually to Mars and beyond.

The Vision for Space Exploration calls for a “building block” strategy of human and robotic missions to achieve new exploration goals, starting with returning the Space Shuttle safely to flight. The Shuttle fleet will focus on completing the International Space Station before being retired. Robotic missions to the Moon are to begin no later than 2008, followed by an extended human expedition as early as 2015. Lunar exploration will lay the groundwork for future exploration of Mars and other destinations. A new spacecraft to support these journeys—the Crew Exploration Vehicle—is to be tested before the end of this decade.

These new vehicles and systems will be launched, controlled and monitored with software. Robotic missions, particularly those traveling far from Earth, will become even more software-intensive as they need to be able to operate independently of continuous communication with Earth. Human spaceflight will always demand safe, reliable software to reduce the risks to those who are exploring for all of us. The IV&V Facility will continue to play a critical role in the success of these vital and exciting missions.

OUR FUTURE

In addition to our direct project services and our research, we at NASA's IV&V Facility will continue to share our unique skills and experience with a growing audience within and outside of NASA. IV&V staff members serve on the NASA Software Working Group, dedicated to improving software development throughout the Agency, and have served on an IEEE team working to revise the IEEE Verification and Validation Standard (IEEE 1012). We provide software expertise to the NASA Engineering Safety Center (NESC) in its independent engineering assessments. We've become a resource for other government agencies seeking to improve their software, and we've talked about our work and our research with the members of the international space and software communities.

While we're reaching for the stars, we still remember our roots. Our partnership with West Virginia University continues to flourish, and we're expanding



our relationships with other local higher education institutions. We're excited about the growing interest in NASA's mission to explore and discover, and the focus on math, science and technology education fostered by our Outreach Program. We continue to build partnerships with local business and community leaders to increase the high-tech opportunities available to West Virginians, and to bring into the area those who haven't yet had the chance to fall in love with our home state.

Our work with NASA projects, our research into software assurance, our outreach to students of all ages, and our participation in our community are commitments we've made both as individuals and as members of the NASA family. We are proud and privileged to serve the NASA vision—

“to improve life here—
to extend life to there—
to find life beyond.”

CREDITS



Cover

"The Earth and Moon." NASA Jet Propulsion Laboratory.
<<http://grin.hq.nasa.gov/ABSTRACTS/GPN-2000-001437.html>>

Page 2-3

"Galaxy." NASA, The Hubble Heritage Team, STScI, AURA.
<<http://grin.hq.nasa.gov/ABSTRACTS/GPN-2000-000897.html>>

Page 4

"Moon Set over Earth." NASA.
<<http://grin.hq.nasa.gov/ABSTRACTS/GPN-2000-001046.html>>

Page 6

"Director Ned Keeler at 10th Anniversary." NASA IV&V Facility.

"Bryan O'Connor at 10th Anniversary." NASA IV&V Facility.

"Congressman Alan B. Mollohan at 10th Anniversary." NASA IV&V Facility.

Page 12

"STS-113 Shuttle Mission Imagery." NASA.
<<http://spaceflight1.nasa.gov/gallery/images/shuttlests-113/hires/sts113e05433.jpg>>

Page 14

"Fisher Receives Space Flight Awareness Award." NASA IV&V Facility.
<http://www.iv.nasa.gov/aboutiv/news/news_fisher.php>

Page 15

"EMU shown during STS-113 Shuttle Mission." NASA.
<<http://spaceflight1.nasa.gov/gallery/images/shuttlests-113/html/sts113e05161.html>>

Page 16

"Natural Color Mosaic of North America." NASA / GSFC / LaRC / JPL, SRTM / MISR Teams.
<<http://photojournal.jpl.nasa.gov/catalog/ftnNumber=PIA04361>>

Page 17

Tschida, Tom. "Active Aeroelastic Wing F/A-18." NASA Dryden Flight Research Center Photo Collection.
<<http://www.dfrc.nasa.gov/gallery/photo/AAW/HTML/EC02020346.html>>

Page 18

"Asia/Noctilucent Clouds, Moon." NASA Johnson Space Center - Earth Sciences and Image Analysis.
<http://eol.jsc.nasa.gov/seop/images/ESC/small/ISS007/ISS007_E-10974.JPG>

Page 20

"Earth's Energy Budget." NASA IV&V Facility.

Page 21

"STS-27, Orbiter Atlantis, Liftoff." NASA Marshall Space Flight Center.
<<http://grin.hq.nasa.gov/ABSTRACTS/GPN-2000-000058.html>>

Page 22

"Artist rendition of ULDB at float." NASA.
<<http://www.wfnasa.gov/~code820/pages/gallery.htm>>

Page 24

"The Reflection Nebula in Orion." NASA The Hubble Heritage Team.
<<http://grin.hq.nasa.gov/ABSTRACTS/GPN-2000-000888.html>>

Page 25

"EMU shown during STS-113 Shuttle Mission." NASA.
<<http://spaceflight1.nasa.gov/gallery/images/shuttlests-113/html/sts113-306-003.html>>

Page 27

Cuillandre, Jean-Charles. "The Orion Nebula from CFHT." NASA Canada-France-Hawaii Telescope Corporation.
<<http://apod.gsfc.nasa.gov/apod/ap040315.html>>

Page 29

"Hubble Above Earth." NASA.
<<http://spaceflight1.nasa.gov/gallery/images/shuttlests-109/hires/sts109-730-034.jpg>>

Page 31

"STS-113 Shuttle Mission Imagery." NASA.
<<http://spaceflight1.nasa.gov/gallery/images/shuttlests-113/hires/sts113e05433.jpg>>

Page 32

"James Webb Space Telescope." NASA IV&V Facility.
<http://imgsrc.hubblesite.org/huldb/2003127/images/allformats/large_web.jpg>

Page 33

"Trifid Nebula." NASA/JPL-Caltech/J. Rho (SSC/Caltech).
<http://www.nasa.gov/images/content/109113main_image_feature_272_ghfull.jpg>

Page 35

"Mars Reconnaissance Orbiter." NASA IV&V Facility.
<<http://photojournal.jpl.nasa.gov/tiff/PIA04241.tif>>

Page 37

"National Polar-orbiting Operational Environmental Satellite System." NOAA Satellite and Information Service.
<<http://npoess.noaa.gov>>

Page 39

"The A-Train." NASA.
<http://www.calpo.larc.nasa.gov/resources/image_gallery.php>

Page 40

"Computer." Stockbyte

Page 43

"STS-58 Launch." NASA Kennedy Space Flight Center.
<<http://grin.hq.nasa.gov/ABSTRACTS/GPN-2000-000756.html>>

Page 44

"SWIFT at the Kennedy Space Center." NASA.
<<http://mediaarchive.ksc.nasa.gov/detail.cfm?mediaid=23497>>

Page 47

"Hypersonic Flight Vehicle X-43C." NASA Marshall Space Flight Center.
<<http://nix.ksc.nasa.gov/info/sessionid=2mnp1tdg23g4g?id=MSFC0202010&orgid=11>>

Page 48

"Montage of Neptune and Triton." NASA Jet Propulsion Laboratory.
<<http://grin.hq.nasa.gov/ABSTRACTS/GPN-2000-001983.html>>

Page 51

"Magnificent Details in a Dusty Spiral Galaxy." NASA The Hubble Heritage Team, STScI, AURA.
<<http://grin.hq.nasa.gov/ABSTRACTS/GPN-2000-000933.html>>

Page 53

"Artist's Concept of Mars Exploration Rover." NASA Jet Propulsion Laboratory.
<<http://photojournal.jpl.nasa.gov/catalog/PIA04413>>

Page 61

Ross, Jim. "NASA's F-15B Active Flies over the Desert near Boron, Calif." NASA Dryden Flight Research Center.
<<http://www.dfrc.nasa.gov/gallery/photo/F-15ACTIVE/HTML/EC96-43780-2.html>>

Page 63

Cuillandre, Jean-Charles. "M17: Omega Nebula Star Factory." NASA Goddard Space Flight Center, Canada-France-Hawaii Telescope Corporation, Hawaiian Starlight.
<<http://apod.gsfc.nasa.gov/apod/ap021210.html>>

Page 64

Cuillandre, Jean-Charles. "M17: Omega Nebula Star Factory." NASA Goddard Space Flight Center, Canada-France-Hawaii Telescope Corporation, Coelum.
<<http://apod.gsfc.nasa.gov/apod/ap040315.html>>

Page 66

"The Education Outreach Team." NASA IV&V Facility.

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"Kindermant." NASA IV&V Facility.

Page 68

Rittenhouse, Ron. "Former NASA Astronaut Frank L. Culbertson, Jr." Dominion Post.

Page 69

Rittenhouse, Ron. "Rocket Boy." Dominion Post.
Rittenhouse, Ron. "Former Pilot Louis Carfagno." Dominion Post.

Page 70

Rittenhouse, Ron. "Day in Park." Dominion Post.

Page 71

"FSU Lifelong Learners." NASA IV&V Facility.

Page 72

"WVU Co-op Students Work on Developing a Shuttle Simulator." NASA IV&V Facility.

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"NASA Interns." NASA IV&V Facility.

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"2004 SEAP and SHARP students." NASA IV&V Facility.

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"Bill Jackson." NASA IV&V Facility.

Page 77

"The NASA Team." NASA IV&V Facility.
"John Marinaro Serving in Germany." NASA IV&V Facility.

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"Clouds and Sunlight over Indian Ocean." NASA Johnson Space Center.
<<http://grin.hq.nasa.gov/ABSTRACTS/GPN-2000-001065.html>>

Page 81

"NASA Facility Sign." NASA IV&V Facility.

Page 82

"Moon, Mars and Beyond." NASA Exploration Systems.
<<http://www.exploration.nasa.gov>>

Page 84

"Floating Free." NASA.
<http://www.nasa.gov/multimedia/imagegallery/image_feature_286.html>

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